ELEMENTARY SCIENTIFIC KNOWLEDGE

(Matriculation Course)

MUKERJI

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(Matriculation Course)

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PREFACE

This book is a school textbook on Elementary Scientific Knowledge primarily intended for the Matriculation and similar Examinations.

The material contained in the book has been provided in accordance with the syllabus for the Matriculation Course as laid down by the University of Calcutta. Up-to-date no suitable textbook in English is available, and the scheme of the book had to be built up. This building up was greatly facilitated by my coming in direct touch with the school teachers who joined the University Teachers' Training Course. As a teacher I could see what parts of the work were most difficult for the student to understand; to see what examples conveyed a true account of a principle involved; and to decide how much structural detail was necessary to illustrate that principle. Such was the synthesis of this book, and it is hoped it will provide a guide to the teachers, as well.

My thanks are specially due to Mr. Santosh Kumar Roy, M.Sc., who wrote the chapters on Geology and Astronomy.

D.M.

ZOOLOGY DEPARTMENT,
UNIVERSITY COLLEGE OF SCIENCE & TECHNOLOGY,
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PART I
PHYSICS
CHAPTER 1
MATTER

Plants and animals are living things. Earth, stone, iron and water are non-living things. We see the living and non-living things with our eyes and can feel or touch them with our hand. If we lift them we find that they have weight. A thing may be light or heavy, big or small. Each thing occupies space and has weight.

All such things as occupy space and have weight, are known as matter. We often speak of matter as a substance or a thing.

A definite portion of matter is called a *body*; the cricket ball is a body. The space it occupies is its *volume*. The amount of matter in a body is called its *mass*. The sun has a mass larger than the earth.

Properties of matter—

Matter not only possesses weight, but also exhibits certain other features. It is divisible : we can divide and sub-divide a thing till it is broken into small particles. Each tiny particle nonetheless is matter. The particles tend to cling to one another.

A rubber band can be stretched but it returns to its former length as soon as the pressure is released. We say it is elastic. Springs are made of steel because steel possesses elasticity. Lead not being elastic, is useless for making springs. Certain materials are more elastic than others and quickly recover their form if altered by a sudden pressure.

Things which apparently seem continuous, contain pores or interstices which are too fine to be seen. Water oozes out from an unglazed earthen pot on account of pores in the vessel. Water could be forced by a very high pressure into a solid lead or iron bar which seemed impervious to the penetration of a liquid. Sugar, if dissolved in water, disappears in it without altering the volume of water. These could be possible owing to the existence of spaces or pores in the body.

The matter is therefore said to have the following general properties :—

(*i*) Weight, (*ii*) Volume, (*iii*) Divisibility, (*iv*) Cohesion, (*v*) Elasticity, (*vi*) Porosity.

The three states of matter—

Matter exists in the three states, namely, *solid*, *liquid* and *gaseous*. Iron, stone and ice are called solids. Water, alcohol, oil are liquids. Steam, oxygen, air are gases. Liquids and gases are known as *fluids*.

The solid has definite shape, and the matter in it is in compact form. A solid substance does not easily fall to pieces unless torn by an external force. A solid rests where it is placed unless moved by an outside force.

The liquid has no shape of its own ; it takes the form of the vessel in which it is kept. It tends to run out in a horizontal direction.

A gas unlike a solid or liquid has the tendency to spread throughout the vessel in which it is kept and fills the entire space within its reach. This is possible because the tiny invisible particles of it are highly mobile. A gas is also compressible, hence we can force a large quantity of it within a limited space.

A matter can exist either in one of the states, namely, solid, liquid and gaseous, or in all the three states.

For instance, ice, water and steam respectively represent the solid, the liquid and the gaseous state of one and the same substance, namely, water.

Water turns at ordinary temperature into water vapour, and if boiled is converted into steam. Both the water vapour and steam on cooling condense into water. Water, if sufficiently cooled down, is frozen into ice. Ice melts by heat into water. A matter thus can be changed from one state to another. Often the passing of matter from one state to another is effected by heating or cooling or by the application of a force. Air and carbon dioxide gas can be liquefied and turned into solid blocks by low temperature and high pressure. Camphor, however, which is in the solid state, readily passes into the vapour or gaseous state. The vapour escapes into the surrounding air. This is the reason why we do not find any trace of camphor kept exposed in a cupboard.

The passing of matter from one state to another, is known as a *physical change*; and this should be distinguished from a *chemical change* where the composition of the substance itself is affected. Thus when coal burns, an ash and a number of gases are produced. The product is altogether a different substance from the original one and the coal ceases to be coal. This is a chemical change. In physical change there is no change in the composition of the substance, water has the same chemical composition whether it be in the form of ice, water, vapour or steam. In physical change there is a change in the appearance only, the total weight of the substance transformed remaining the same as before.

In passing from one physical state to another, the substance generally undergoes a change in volume. One cubic foot of water, if changed to steam, can occupy 1,700 cubic feet. Water, as it changes into ice, increases

in volume. In cold countries, the water pipe sometimes bursts owing to the expansion of water on being frozen into ice. Most metals, however, unlike water, contract as they change from the liquid to the solid state. A molten fluid like that of lead when cast into a mould, shrinks as it solidifies ; so the metal casting can be taken out of the mould without breaking the latter.

The temperature at which the change of state takes place is different for different substances. Thus while ice melts at 0°C, paraffin melts at 50°C and iron at about 800°C. Water is converted into steam at 100°C.

FORCE

A body, say a chair, if it is pushed, moves. A suitable force is necessary to set a thing in motion. Matter is defined as that which can be moved by force.

Forces are of various types. The steam engine moves with a force. When the blacksmith strikes his hammer, he exerts a force. These are different from the forces of gravity and friction.

A number of forces may act on a body. An object lying on a table is pulled by the earth, but the table exerts an upward force which counteracts the downward force of gravity and thus prevents the body from falling.

You may have heard the story how the falling of an apple from a tree led Newton to think out that masses or bodies are pulled by the earth towards its centre and how from this observation he set up the theory of gravitation.

When things tumble down from a height they fall to the ground. Water flows down from higher to a lower level. A cricket ball thrown up in the sky first shoots high, stops for a fraction of a second in the air, then begins to fall downward. It moves faster as it comes nearer

the earth. Everything is pulled towards the earth by this unseen force called *gravity*.

The bigger is the mass, the greater is the pull. All masses attract each other in a similar way, but the earth's pull owing to its very large size, is so great that the pull exerted by other bodies appears to be quite insignificant.

The gravitational force can be easily measured by a spring balance. The earth's pull on the object is called its weight. Some substances are heavier than others, and this means that things like lead and iron are pulled more strongly than feathers and corks.

Now, the nearer an object is to the centre of the earth the greater will be the force of attraction, and the further away from the earth's centre, the less will be the strength of the earth's pull. Hence the weight of a thing weighed on the top of a mountain, will be less than that at the sea side.

The force of gravity, however, is not the only force acting on matter. A ball set in motion on a smooth ground gradually loses speed. If the ground is rough the motion is more quickly lost and the ball comes to a stop. The force that retards the progress is known as *friction*. It prevents the sliding of one body against another. Friction prevents the slipping of tyres on the road. Machinery is oiled to reduce friction.

When a top spins round, or a wheel revolves, or a pebble is whirled round by a thread tied to it, the matter is under the action of a force which tends to draw away the matter from the centre of the pull. It is known as the *centrifugal force*. The potter in shaping an earthen vessel, uses the centrifugal force.

A force may also be generated by heat as by the expansion of steam. This force is different from gravitational or centrifugal force or frictional force.

into steam and in driving the locomotive engine or doing a work. The energy is thus transformable into work.

A stone on the top of a cliff possesses a hidden energy which comes out as the stone falls. The falling stone does work. The amount of work done by a falling body can be determined by a mechanical contrivance in which a paddle is made to rotate by the falling weight.

Energy is therefore defined as the capacity for doing work.

PHYSICAL BALANCE

Weights of things is easily taken by means of a weighing machine or spring balance. For accurate determination

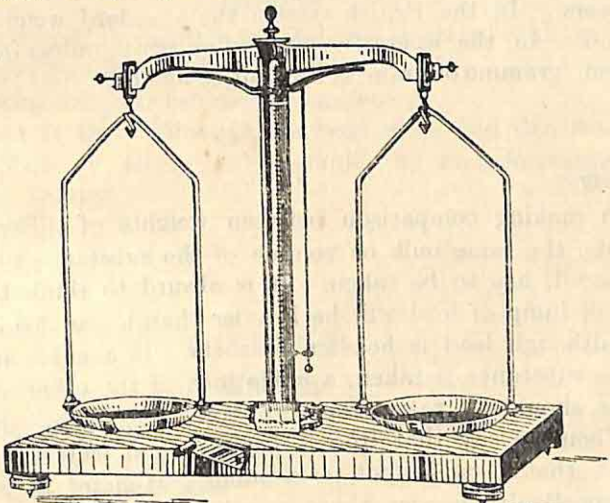

Fig. 1. Physical balance

of weights of smaller objects, however, a delicate instrument called the physical balance is necessary. A weighing

balance consists of a beam supported on a tall column (Fig. 1). A pan is supported at each end of the beam. A pointer is attached to the middle of the beam.

Methods of use: The beam is raised by means of a handle at the bottom of the instrument. As the beam is elevated, it rests on an agate knife-edge, and the pans rise up. The weights are placed on the right-hand pan and objects to be weighed are placed on the left-hand pan. The weights in the weight box should be transferred to the pan with the forceps. The movement of the pointer over a scale is to be watched during weighing. The beam should be brought into the resting position by a turn of the handle after weighing.

In our Indian system weights are expressed in terms of 'seers'. In the British system the standard weight is 'pound'. In the scientific system or centigradegramme system, 'gramme or gram' is the unit of weight.

Density—

In making comparison between weights of different objects, the same bulk or volume of the substance to be compared, has to be taken. It is absurd to think that a small lump of lead will be heavier than a cart-load of tin, although lead is heavier than tin. If a cubic inch of one substance is taken, a cubic inch of the other substance should be taken for comparison of the weights.

When we say that iron is heavier than water, it is meant that a cubic foot or a cubic centimeter of iron is respectively heavier than a cubic foot or a cubic centimeter of water.

This is put in a scientific language in a different way. It is said that the density of iron is greater than the density of water. Iron sinks in water being more dense

than water. Cork floats in water, its density being less than that of water.

Now, *density* is defined as the mass per unit volume.

The weight of one cubic centimeter of water at 4°C is one gram or one gramme. Therefore the density of water is 1. When density of a substance is compared with that of water, what we get is a relative density, and the relative density is known as the specific gravity. The relative density or specific gravity of mercury is 13·6. It means that it is 13·6 times heavier than the same volume of water.

Questions

1. What are the different states of matter? Can you change a liquid into a solid form?
2. Distinguish between matter and energy.
3. What is the distinction between mass and density?
4. Explain by citing an example the transformation of energy.

CHAPTER II

WATER

PHYSICAL PROPERTIES OF WATER

Water finds its own level—

Water is a liquid and takes the same form as the vessel in which it is contained. If two water reservoirs stand at different heights and communicate with each other, the water flows from the one to the other at a lower level till the level of the water in the two is equalized.

The pressure of the flow depends not on the quantity of water but on the difference in the levels of water. The tendency of water to run till its upper surface is horizontal or level, is expressed by the saying that water finds its own level, and is shown by the following experiment: A set of vessels of various shapes and sizes (Fig. 2) are connected at the bottom by a horizontal tube so as to put all of them in communication with one another.

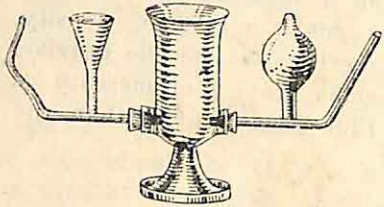

Fig. 2. Level of water in communicating vessels

If a sufficient quantity of water is poured into any one of the vessels, it is found that the water passes into others and stands at equal heights in all the vessels irrespective of the shape or size of the vessels or the quantity of water contained in each.

The water supply of a town is made on the above principle.

Water is first pumped into a large reservoir which is placed high on the top of a frame-work. The water is allowed to run down from the reservoir by gravitation, and is distributed by water pipes to different parts of the town. The pipes may run through a high or low ground, but this is immaterial so long as they are below the level of the main reservoir at the supply station.

If a house is lower than the reservoir at the supply station, the water runs up the pipe into the tap, and the constant supply of water to the house is maintained.

If, however, a cistern or water tap in a house is higher up than the main reservoir, the water does not reach the tap, and recourse has to be taken to a water pump for feeding the cistern or the tap.

WATER EXERTS PRESSURE

Lateral and downward pressure of water—

A liquid has the tendency to spread in a horizontal direction, therefore, if it be held in a vessel, it pushes sideways the walls which prevent it from running out. It also presses on the lower surface of the vessel. This pressure acts vertically down and is called the downward pressure.

If a spherical vessel be filled with water and apertures be made at any point on its wall, the water streams out through them showing that the pressure is exerted on all points of the surface which is under water.

The pressure on a point at the bottom of the vessel is not the same as at any point higher up the sidewall. The pressure varies according to the depth of water. It increases with the depth. This is shown by the following experiment:

A tall can with a series of apertures on the upper, middle and lower parts of its body, is taken (Fig. 3). The apertures are closed by corks and the can is filled with water. If the corks are not tightly fitted in, they will be thrown out by the pressure of water in the can. On opening them, jets of water issue, but the one from the aperture on the lower part of the can, comes out more forcibly than the middle jet, and still more forcibly than the one issuing out from the aperture higher up the

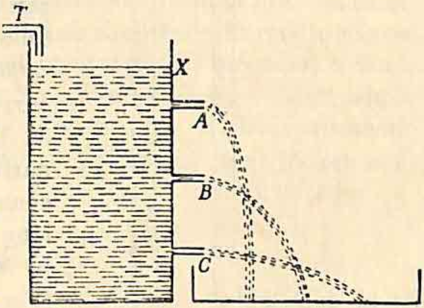

Fig. 3. Lateral pressure of a liquid:
A, B, C—water-jets issuing from different levels
X—water can
T—water tap

can. The water-jet is longer where the pressure is greater. The pressure can be felt by applying the thumb on the aperture.

The pressure at any point immersed in water does not depend on the total quantity of water in the can, but on the height of the column of water standing above the point.

If a second can with a wider diameter but of the same height as the first can, be taken, it will hold larger quantity of water than the first can, but the pressure at any point in it will be the same as at the corresponding point on the other, provided the height of water in both the cans is exactly equal.

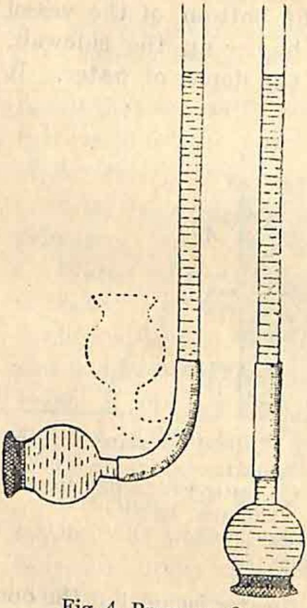

Fig. 4. Pressure of a column of water

The lateral and downward pressures exerted by water or any other liquid can be demonstrated by the following simple apparatus.

The mouth of a funnel is covered by a tightly stretched thin rubber sheet. The narrow end of the funnels is connected with one end of a long glass tube. This is done by means of rubber tube (Fig. 4). The glass tube is held vertically up and is filled with water. The rubber sheet bulges out by the weight of the column of water in the glass tube. By bending the connecting rubber tube, the funnel can be placed in different positions and the extent of bulging of the rubber sheet which indicated the pressure on it, should be noted. The

height of the water column in the glass tube can be altered and the corresponding change in pressure can be noted.

The pressure on a surface or area of a thing kept immersed in water, is equal to the weight of the column of water standing above it. Now one cubic foot of water weighs $62\frac{1}{2}$ lbs. and in C.G.S., 1 c.c. of water weighs 1 gram, therefore, if the height of water standing above any area be known, the weight of the column of water is easily calculated. This multiplied by the area of the surface immersed in water gives the total pressure on the surface under water.

As the weight of the column of water increases with the depth of water, animals living at great depths of the sea, are subjected to enormous pressure. They are, however, not crushed by the heavy weight of water pressing on their body, being accustomed to such a condition of life. Rather if they are brought to the surface their body bursts to pieces owing to sudden release of pressure. If, however, a land animal tries to go down under the sea it may be crushed by the downward pressure of water. A diver protects himself against this pressure by wearing steel jacket and helmet.

Upward pressure of water—

While an object sinks in water by its weight it is forced up by the upward pressure of water.

The upward push or upward pressure is called the upthrust of a liquid. A body goes down or sinks in water by its weight but its downward journey is opposed by the upthrust of water. When the upward force is stronger than the downward force, the body floats.

If the downward force due to gravity be such that it cannot be counter-balanced by the upthrust of water the body sinks in water.

The upthrust or upward force of water is exercised whenever a body is put into water. If an empty vessel be pushed with its mouth up straight down into water, a resistance is felt, the vessel being pushed up from below. The upthrust is felt if the palm of the hand is outstretched and struck flat against the surface of water.

Since the upthrust tends to raise up a body and thus counteracts the downward force of gravity, a body immersed in water loses a portion of its weight and seems therefore lighter in water than in air. The loss in weight

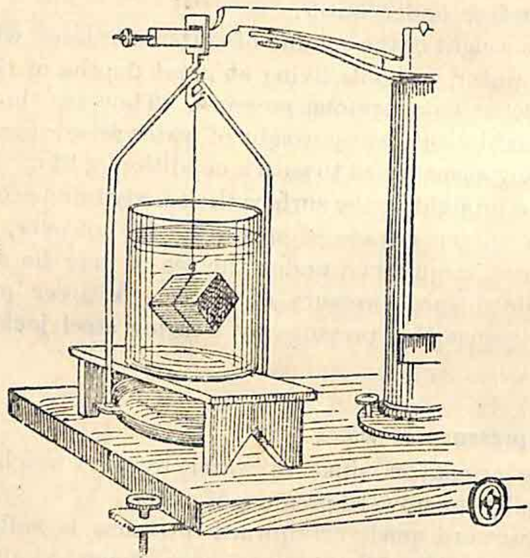

Fig. 5. The upthrust of a liquid

can be determined by weighing a body in air and weighing it again in water. The weighing in water can be done by suspending the object by means of a thread and immersing it in water. The difference between the two weights gives the loss in weight (Fig. 5).

Now, if a body is immersed in water it displaces water. If a piece of lead or any other object be plunged into a beaker full of water, the water overflows from the beaker. If a larger object be immersed, a larger quantity of water overflows being displaced by the object. The volume is found by collecting the overflowing water.

The volume of water displaced is found to be the same as that of the object immersed in water.

If an object such as a piece of wood, floats in water, a part of it is always immersed in water. The volume of water displaced in such a case is the same as that of the portion under water.

It is found that the weight of water displaced by a body immersed in water is equal to the weight lost by the body when under water. This is known as *Archimedes Principle* and can be stated as follows :—

A solid body immersed in water displaces water and loses a part of its weight equal to the weight of the water displaced.

The upthrust of water is equal to the weight of displaced water. If a larger volume of water is displaced the upthrust will be greater. A larger volume of water will be displaced if the body is voluminous. A tin foil, if beaten into a small lump, sinks in water. If the foil is spread in the form of a ship so as to occupy a larger volume it floats in water although it has the same weight as before. Flotation therefore depends upon the volume of displaced water.

Buoyancy of water—

Corks float while iron sinks in water. Bodies which are lighter than water float, while those heavier than water sink in it. An iron piece floats in mercury, the

latter being heavier than iron. A body heavier than water, however, can be made to float if a larger volume of water could be displaced. A steamer, for example, made of iron or steel, makes its voyage in water. It does not sink for its total weight opposed and balanced by the upthrust of the water. The upthrust increases if a larger surface is presented to water so as to displace a larger volume of water. A boat therefore for the purpose of enlarging its capacity for holding goods, is not built high but its surface area is increased by making it flat.

Transmission of liquid pressure—

Water is incompressible and if an external pressure be applied anywhere on its surface it is transmitted equally to all parts of the water. If water is contained in a spherical vessel with an outlet on the top (Fig. 6) and 1 lb. of pressure is applied to the water through this outlet, all parts of the sphere equally become subjected to a pressure of 1 lb. The total pressure therefore is the sum of the pressure on each point of the vessel and is many times the original pressure. The principle that pressure applied to any part of water is transmitted to other parts finds application in the making of a hydraulic press.

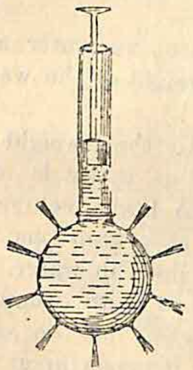

Fig. 6. Transmission of liquid pressure

Hydraulic press—

The hydraulic press is made up of a metal U-tube one arm or limb of which is narrow, and the other is of large

diameter, say, four times the other (Fig.7). The areas of the two limbs are therefore in the ratio of 1 : 16. The U-tube is filled with water. A pressure applied to the narrow limb will be multiplied 16 times in the larger limb. Watertight pistons are fitted into the open ends of both the tubes. By placing a small load or weight on the piston of the narrow limb, greater pressure is obtained on the piston of the other limb, and so a heavy load can be raised or pressed by placing it on the piston of the wider limb.

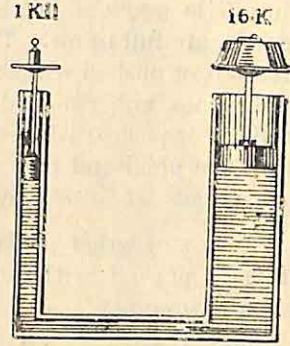

Fig. 7. Hydraulic press

Questions

1. Explain why a ship floats in water.
2. How would you show that water finds its own level ?
3. State Archimedes Principle.
4. What do you understand by the downward pressure of water ?

CHAPTER III

AIR

PHYSICAL PROPERTIES OF AIR

Air is a gas or rather a mixture of gases. It is colourless and has no odour. Therefore we do not see it or smell it although we are constantly breathing it. We are moving through it but we do not perceive it till the wind blows.

It fills all the spaces around us and moves in all directions. The little crevices in the walls or the so-called empty vessels, are full of air. If any empty phial or tumbler, be inverted or pushed straight down within the basin of water, water does not rise and fill the phial. If the phial be inclined or pushed with its mouth up, bubbles of air escape from the phial and pass into the surrounding air. Water now rushes in to occupy the space made vacant by air.

A box whether it is open or closed, contains air. If it is packed with articles it contains less air than when it is empty.

A cycle tyre or a football is inflated with air. This is compressed air. The compressed air has more weight and exerts greater pressure than the ordinary air. If a puncture is made at any point of a tyre or football, the compressed air rushes out of it till the pressure inside the tyre or the ball is the same as that of the ordinary air outside it.

Air exerts pressure in all directions. If a large quantity of air is pumped into a small space, air gets compressed and the pressure increases. The rise of air-pressure also occurs if a given volume of air is squeezed into a smaller space. On the contrary, the pressure falls if the same quantity of air is allowed to spread or fill a larger space. The relation between pressure and volume of air is realized if we suppose that air is composed of a number of very minute invisible particles which are constantly moving. If air is enclosed within a vessel, its particles collide against the wall of the vessel, rebound and again impinge on the wall. The impact on the wall gives rise to pressure. As the space within the vessel is reduced, collisions will be more frequent and the pressure on the wall will rise high. If the space is enlarged the impacts on the wall of the vessel become less. Hence the pressure falls as the

volume is increased. If the air particles are distributed over a large area, the air becomes less dense and it is said to be rarefied. Rarefied air is lighter than the compressed air and its pressure is less.

The following experiments show the force of air pressure :—

(*i*) Two hollow hemispheres called the *Magdeburg hemispheres* fit closely to each other at their edges and form a hollow sphere (Fig. 8). One of the hemispheres is provided with a stop cock. If air be exhausted from the sphere by joining the stop cock with a suction air-pump great force is needed to separate the two hemispheres. The latter are held firmly together by the pressure of the atmospheric air, there being no air inside the sphere.

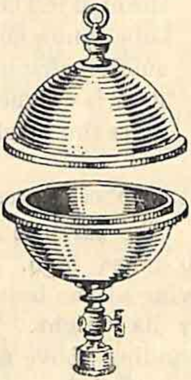

Fig. 8. Magdeburg Hemispheres

(*ii*) Fill a glass with water and apply a thin card board over the mouth of the glass. See there is no air inside the vessel. If the glass with the paper be inverted as in the figure, neither the water nor the card board falls (Fig. 9).

Fig. 9. A Card supported by atmospheric pressure

The card board is held in its place by the atmospheric

air which presses it up and balances the weight of water inside the glass.

Air has weight and this can be determined in the following way :—

A flask is fitted with a stopper, and a glass tube runs through it. The flask contains air. It is weighed. The glass tube is now connected by means of a rubber tube with a suction air-pump and is emptied of its air. The empty flask is weighed. The difference between the two weights gives the weight of the air contained in the flask.

Atmospheric pressure—

The earth is surrounded by air which extends nearly 50 miles high. This is the atmospheric air. We are living at the bottom of this ocean of air, and are pressed by its weight. The weight of the vast column of air standing above us is about 15 lbs. per square inch. This pressure is known as the atmospheric pressure.

The envelope of air is not uniform in its density. The bottom layer of air immediately surrounding us, is compressed by the weight of air on the top of it, and this compressed air is always acting on us whether we are out in the open or inside a room. Our fate is therefore like the fishes living under the depths of the sea under a tremendous pressure of the sea water. If the atmospheric pressure to which our body is accustomed, be suddenly withdrawn the body may burst to pieces. The atmospheric pressure diminishes as one ascends or climbs a hill. Air higher up is rarefied. Airmen and mountaineers therefore feel great difficulty in breathing as they ascend high. Often their ears and eyes bleed. Balloons burst at great heights, because the pressure inside the balloon can no longer be balanced by the reduced pressure of the surrounding air.

If, however, one goes down a mine, the column of

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air above him becomes longer and so he is subjected to a greater weight of air.

Measurement of atmospheric pressure—

The atmospheric pressure is pressing on all things; it therefore keeps down the free surface of the water from rising up. Water rises in a tube if air within the tube is removed by suction and a partial vacuum is created. The water is forced into the vacuum by the outside atmospheric pressure. If air be admitted into the tube, the water column in the tube runs down being pressed from above by the air inside the tube.

The instrument by means of which the atmospheric pressure is measured is called a Barometer.

How to make a Barometer—

A glass tube about 35 inches long with one end closed, is completely filled with mercury. A large bowl is now half filled with mercury. The open end of the tube is closed by applying the thumb over its mouth, and the tube is inverted over the bowl. When the mouth of the tube is under the surface of mercury in the bowl, the finger is removed from it, and the tube is held vertically up (Fig. 10). The column of mercury in the tube runs down a little leaving an empty space which is called after the name of the scientist who first devised this experiment. It is known as *Torricellian Vacuum.*

Fig. 10. A Simple barometer
The space A B is called a Torricellian Vacuum. The column of mercury BC is held up by atmospheric pressure. The left-hand tube is filled with water, and the right with mercury.

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Now there is nothing in the tube above the column of mercury which can pull or drag the mercury up. It is the outside air pressing on the free surface of mercury in the bowl, that forces up the mercury in the tube. If this air pressure falls, the mercury column falls. If it rises, the mercury in the tube rises up.

In fact the atmospheric pressure balances the mercury column in the tube. Usually a mercury column about 30 inches in height is supported by the atmospheric pressure; so this height indicates the atmospheric pressure.

If we take, instead of mercury, any other liquid, say, water, a column of water will also be forced high in the tube, but in such a case, water being lighter than mercury the column will be taller than that of the mercury. The atmospheric pressure usually balances a column of water 32 to 34 ft. high, therefore if we use water we should take a tube which is at least 34 ft. high.

Now, a liquid barometer such as the mercury one, cannot be carried from place to place without considerable inconvenience, so a different type of instrument called *aneroid* (without liquid) barometer is used. It is made of a closed metallic box out of which air has been drawn away. A spring is attached to the box (Fig. 11). When atmospheric pressure is high, the top of the box is forced down by it, and when the atmospheric pressure is low the top of the box moves out. The movements of the top of the box are transmitted by means of a

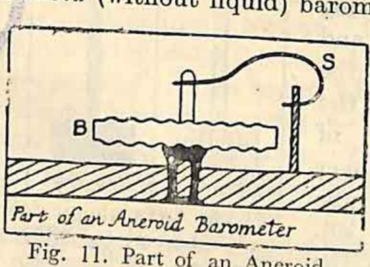

Fig. 11. Part of an Aneroid barometer

B. Empty steel box sealed air-tight and placed on the instrument

S. Metal spring connecting the top of the box with the pointer

spring to a pointer which indicates the variations in the atmospheric pressure.

Weather forecast from barometric readings—

Variation in the density of atmospheric air is of frequent occurrence owing to the flowing in of moisture-laden air from the sea, expansion of air by the solar heat and various other causes. A change in the atmospheric air affects the barometer.

Water vapour is lighter than air and presence of a large amount of it in air, causes a lessening of the atmospheric pressure, and the barometer falls, i.e., the height of the column of mercury in the barometer is less. So when the barometer falls, we say it is going to rain. Again the weight of dry air is greater. So as the barometer rises we know that air is dry. The metereologist predicts from a number of readings if the weather is going to be fine or not.

Determination of altitudes by the barometer—

On the top of a lofty mountain air is less dense than that at the sea level. On the top of a high mountain the barometric height is not more than half its value at the sea level. The greater the height, the less becomes the atmospheric pressure. Hence it is possible to tell the height of any place from barometer readings. From the rise and fall in the barometer, airmen know how high they are flying. When the barometer has fallen half an inch they know that they have climbed about 500 ft. when it has fallen one inch they have climbed about 1,000 feet.

Water Pumps—

Water is forced up a pipe by the atmospheric pressure to a height of about 33 ft. This principle is made use of in making ordinary water pumps.

A barrel is fitted with a piston. The lower end of the barrel is joined with a long pipe which is sunk into water

to be pumped up (Fig. 12). At the bottom of the barrel near its junction with the pipe there is a valve Y. There is also a valve X in the piston. With the upstroke of the piston, a partial vacuum is created in the barrel, the water in consequence ascends the pipe and fills the lower portion of the barrel below the piston. As the piston is drawn up to the extremity, the entire barrel is filled up with water. This water is forced down the spout of the barrel as the piston is worked down. The valve Y works one way and prevents the water in the barrel from flowing down the pipe. With the down stroke of the piston the water from the lower portion of the barrel is forced through the valve X into the upper portion of the barrel. The valve X does not allow water going down from the upper portion of the barrel into its lower portion. This pump will not draw water from the depth of more than 34 feet.

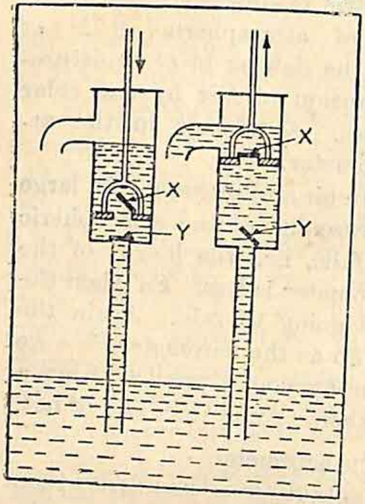

Fig. 12. Water pump
X and Y are valves which open and close as shown

Questions

1. How would you prove that air exerts pressure ?
2. Explain the atmospheric pressure and how it can be measured.
3. State the physical properties of air and compare them with those of water.

CHAPTER IV

HEAT

We feel the warmth of a fire if we stand near it, and can tell by our sense of touch whether a body is hot or cold. But our sense of touch is often deceptive ; any two objects like an iron frame and the wooden door situated in the same room may have the same degree of hotness, but curiously enough, the one feels colder than the other if touched by hand. Our sense of touch does not enable us to know correctly the degree of hotness or temperature of a thing, or, how much of heat is present in a body. But heat is a physical quantity and we can ascertain the temperature and the amount of heat in a body by an indirect method, namely, by noting the changes wrought in a substance by heat. Heat brings out various changes in a body. It effects transformation of matter from one state to another, a solid substance being changed into a liquid or a liquid into a gas. It brings out chemical changes. Fuel is changed into ash. It causes expansion or contraction of matter.

Expansion of solids—

Metals among the solid substances undergo a perceptible change in volume and size if heated. A metal rod increases in length with the rise of temperature, and contracts with the fall of temperature. Some substances expand more than others if heated to the same degree. Brass, for example, expands more than iron ; copper, if cooled, contracts nearly twice as much as glass.

The following experiment can be made to demonstrate the expansion of metals on being heated.

The apparatus called *Gravesande's ring* consists of a metal ring supported on a stand. A hollow sphere made

of brass that just passes through the ring is taken (Fig. 13). The sphere is heated over a spirit lamp. The hot sphere

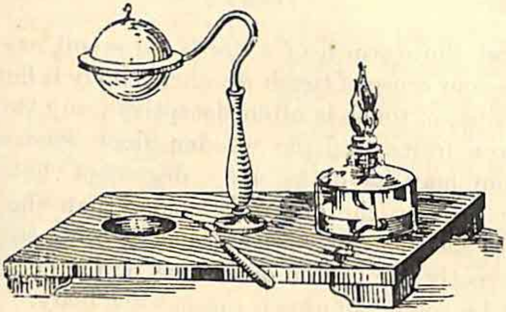

Fig. 13. Gravesande's ring

is placed in the ring. Since it has increased in bulk by heat, it does not pass through the ring but rests on it. It falls through as it cools down on account of contraction.

Expansion or contraction occurs with great force. The force of contraction is shown by the following experiment :—

Two iron bars with a notch in the middle are fixed at a distance from each other on an iron frame. An iron rod which is provided with a screw at one end and a hole at the other end, is made red hot and is placed over the notches. A bolt is now passed through the hole of the hot rod, and a nut is screwed tight at its other end. Cold water is poured on the hot rod. The rod contracts with such force as to break the bolt which prevented it from shortening in length.

The forces of expansion and contraction find practical applications in the design of machinery. Tyres made of metal are heated and as they expand they are slipped on to the wheels, to which they fasten on when they contract. Riveting is done on the same principle. Having regard to the force of expansion, rails are laid in such a way as to leave gaps between consecutive pieces. When trains pass

over them, railway lines become hot by friction and expand. Had no space been left between them they would force each other and bend. In clocks, too, due allowance should be made for the expansion of metal parts in them. The time is determined by the swing of the pendulum. If the length of the pendulum increases under the action of heat, the clock goes wrong. To correct this error caused by expansion of the pendulum, it is made up of a number of rods made of brass and iron. As one of the rods expands and tries to carry the bob down, the other rod carries it upward, thus one set compensates for the effect of expansion of the other.

Expansion of liquids—

Liquids when heated expand more than the solids. Some liquids expand more than others if heated through the same range of temperature. Alcohol, for instance, expands ten times as much as mercury.

The expansion of water can be shown by the following experiment :—

A glass tube with a uniform bore is blown to form a bulb at one end. The bulb is filled with water. The bulb instead of being put directly over a flame, is heated by placing it in a beaker of water which is warmed by a spirit lamp. The tube is held vertically up and a scale is placed alongside its length. As the water in the bulb is warmed it expands and the column of water gradually rises in the tube. The head of the rising column of water can be read on the scale.

The glass tube also expands when hot, but the increase in its size is so small in comparison to that of the water within the tube, that it may be neglected.

The expansion of mercury can be determined by filling the bulb with mercury and noting the rise of the mercury column in the tube as it is warmed.

The relation between temperature and the amount of expansion of a liquid furnishes a basis for the measurement of temperature.

TEMPERATURE

Ice is cold and steam is hot. The degree of hotness in a body is spoken of as its temperature. A cup of hot tea has a higher temperature than a cup of cold tea, and if the two are mixed, the hot tea loses heat and the other gains it, till the mixture has the same temperature. Two bodies are therefore said to be at the same temperature, when being in contact neither can impart nor receive heat from the other.

Temperature is defined as the condition which determines the flow of heat in a body. Temperature is quite different from the quantity or amount of heat in a body. A hot iron ball of large size, for instance, contains a larger quantity of heat than an iron ball of a smaller size even when the latter is as hot as or hotter than the other. If the smaller body be put in contact with the larger body, heat will flow from one at a higher temperature to the other which is at a lower temperature, although the latter may contain a larger quantity of heat in it.

The flow of heat depends on the difference in temperature and not on the quantity of heat. The temperature is analogous to the level of water. If two reservoirs be connected by a pipe water flows from the one which is at a higher level to the one at a lower level. If both the reservoirs are at the same level the water does not pass from the one to the other, no matter how much difference there is in the quantities of water between the two.

A clear distinction thus exists between the temperature and the quantity of heat.

Construction of Thermometer—

A thermometer is an instrument for recording the temperature of a body.

In making an ordinary thermometer a liquid is put in a glass tube, and the rise of temperature is found by the expansion of the liquid in the tube. In filling the tube, mercury is preferred to water or any other liquid as it expands uniformly with the rise of temperature and is not easily converted into a gas or a solid. Water does not expand uniformly with the gradual rise of temperature and is not so sensitive as the mercury. Moreover, a longer tube would be required if it is to be filled with water instead of mercury.

A mercury thermometer is made in the following way :—

A glass tube with a uniform bore and having a bulb at one end is taken. The bulb and a portion of the tube are filled with mercury and the tube is sealed after air has been driven away from it.

The bulb containing mercury is placed within a funnel packed with ice (Fig. 14). The column of mercury in the tube falls and stands still as the mercury is cooled down to the temperature at which the ice melts into water. The position of the head of the mercury column is marked by a scratch on the tube. This is taken to be the lowest point in the thermometer and represents the temperature of the melting ice. It is called the *freezing point* of the thermometer. The thermo-

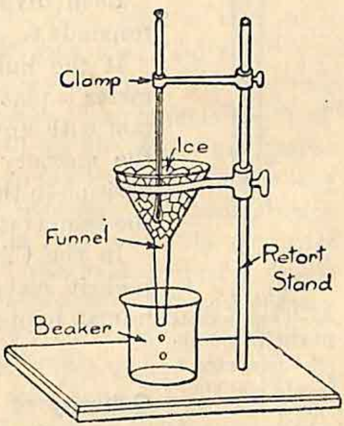

Fig. 14. Determination of the freezing point of a thermometer

meter is then placed in a current of steam. The mercury column shoots high owing to its expansion by heat. As the head of the column becomes steady, it is marked on the tube by a scratch. This represents the temperature of the boiling water. It is called the *boiling point* of the thermometer. The boiling point and the freezing point are known as the fixed points of a thermometer.

Now two or three types of scale are in vogue.

In the *Centigrade* scale the temperature of the melting ice is taken to represent the 0° and the boiling point of water as 100°. The distance between the freezing and boiling points on the thermometer is graduated or divided into 100 equal parts and marked on the tube of the thermometer (Fig. 15).

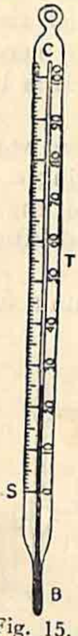

Fig. 15.
A—Thermometer
B—Bulb of the thermometer
C—Thermometer graduated in centigrade scale
S—Freezing point
T—Scale

In the *Fahrenheit* scale the freezing point is marked 32°F and the boiling point 212°F, and 180 marks are put between the highest and the lowest point in the thermometer.

Each division in the thermometer corresponds to one degree of temperature.

If the bulb of the centigrade thermometer is placed in water or is put into contact with any other object and the head of the mercury column stands at the 30th division in the thermometer scale, we know the temperature of the water is 30°C.

In the Clinical thermometers, the Fahrenheit scale is followed and the normal human temperature is marked 98·4°F.

Quantity of heat—

In finding out the degree of hotness of a body by a thermometer, we have taken

the temperature of ice and steam as the standard. In making a measurement of a quantity of heat we have to fix a standard, too. The unit quantity of heat is defined as the amount of heat required to raise the temperature of 1 *c.c.* or 1 *gram* of water through 1°C. Therefore, if two grams of water are raised through 1°C we know two units of heat have been used. We can thus find by calculation the quantity of heat in a body, by noting the temperature which a known volume of water will attain if a hot body be put into it.

Different substances require different amounts of heat to raise the body through a given range of temperature. Or, in other words, the same quantity of heat will raise different substances to different levels of temperature if the mass be equal. One unit of heat for example, would raise a gram of mercury to 30°C, a gram of silver to 20°C, and a gram of copper to 10°C.

Expansion of gases—

Gases expand when heated. The increase in volume of a gas is remarkably greater than that of a solid or a liquid substance heated to the same degree. Air expands like a gas by the action of heat. The expansion of air by heat can be demonstrated in the following way—

A small flask is fitted with a cork through which a long glass tube passes up to the exterior. The flask, though it seems apparently empty, in reality contains air under the atmospheric pressure. The flask is turned upside down and the open end of the tube is put under water contained in a cup (Fig. 16). The water is coloured. A column of water from the cup rises in the tube and its height is noted. The flask is now gently heated. The air becomes hot and expands pushing down the water column in the tube. As the flask is cooled, the

air within the flask diminishes in volume creating a partial vacuum : the water is sucked into the tube.

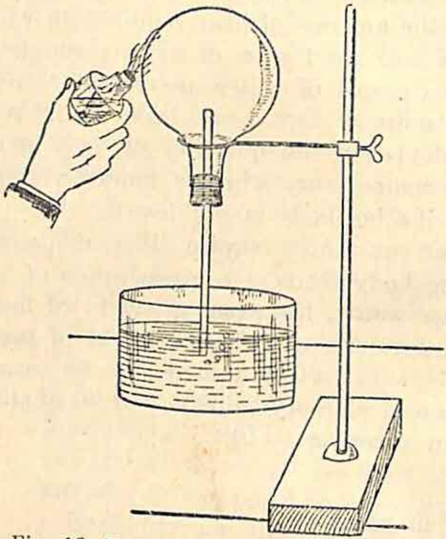

Fig. 16. Expansion of air when heated

Effect of heat on water—

Water on being gently heated gradually rises in temperature and escapes as vapour. If more heat is imparted to the water a state is reached when the latter does not get hotter still but begins to boil and is converted into steam. Once the boiling point is reached all the heat goes in turning water into steam without raising any further temperature. The temperature of water when this conversion is made, remains constant and, is known as the boiling point of water.

The steam, on coming in contact with a cool surface, condenses to water. If the temperature is extremely lowered, water is frozen into ice. Ice melts by heat into water and no change of temperature occurs at this time till

all the ice has melted into water. The temperature at which water is frozen into ice is known as the freezing point. It is marked o°C in the thermometer.

Heat effects in water expansion as well as the change of state, and the result of heat on water can be summed up as follows :—

(*i*) Ice at 0°C contracts and changes to water at 0°C.

(*ii*) Water at 0°C contracts until it reaches the temperature of 4°C.

(*iii*) Water at 4°C expands and goes on expanding until it reaches 100°C.

(*iv*) Water at 100°C turns to steam and expands.

Questions

1. Distinguish between the temperature and the quantity of heat.
2. On what principle is a thermometer constructed ?
3. What are the effects of heat on water and air ?
4. Describe an experiment to show that metals expand by heat.

CHAPTER V

TRANSMISSION OF HEAT

CONDUCTION

If one end of a metal rod be placed in a flame and its other end is held by hand, it is found that the end further away from the flame gradually becomes hot, but the part near the flame is hotter than the part far away from the flame. This is because heat slowly travels along the rod from the heated end.

Heat is a form of energy. The tiny invisible particles called the molecules of the metal are set into vibration by the heat energy. The molecules next to the vibrating molecules, begin vibrating as soon as the heat from the neighbouring vibrating particles is passed on to them and so on, until the vibrating reaches the extreme end of the rod. Thus heat energy is being transferred on from one part to the other of the rod by the vibration of molecules of the metal, but no material thing is seen to be passing from one end of the rod to the other during the passage of heat. This mode of transference of heat is called conduction.

Substances which let heat easily pass through them are called good conductors of heat. While others which do not allow heat to travel through them are known as bad conductors of heat. Metals, cotton, linen are good conductors of heat, while asbestos, mica, wood, fur, silk, wool are bad conductors of heat. Air and water are also bad conductors of heat.

The wooden handle of a hot saucepan does not get hot, because heat fails to pass through the wood. Our winter clothes are made of wool, because wool and the air held in the little cavities of the knitted wool are bad conductors of heat. Ordinary cotton or linen materials are not suitable for winter clothing as they are conductors of heat.

A woollen blanket is a bad conductor of heat, so blocks of ice are covered up with a piece of blanket to prevent ice from being melted by outside heat.

Articles made of good conducting material are cold to the touch since heat is conducted away through them from our body, while those made of non-conducting substances feel warm because they do not carry away heat from our body.

Wire gauze is a good conductor of heat, and so if it is placed over a jet of gas and the gas is lighted below

the gauze, no flame will be found above it (Fig. 17). The reason is that heat is conducted away by the gauze

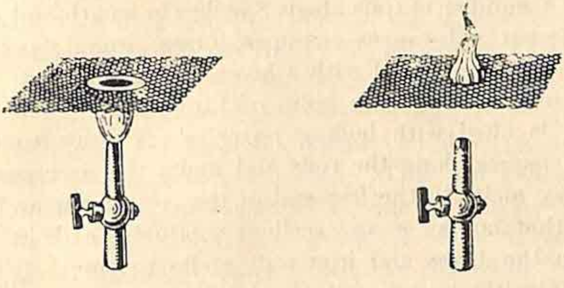

Fig. 17. Wire gauge over a flame

so quickly that the gas passing above the gauze does not get enough heat from the flame to catch fire.

Now every substance is ignited at a certain temperature which may be called its *ignition point*. Substances like petrol, the ignition point of which is low, are easily inflammable, while substances having higher ignition point will not catch fire at that temperature.

The above principles are applied in making the Davy safety lamp for use in mines. The lamp has a wire gauze all round it. In a mine where there is a dangerous inflammable gas, an ordinary lamp will set fire to the gas and an explosion would occur; but if a Davy lamp be used some of the mine gas passing inside it through the wire gauze burns within the lamp and the heat of the burning flame is conducted away so quickly that the gas outside the gauze is not ignited and hence no explosion occurs.

Now among the conductors some conduct heat better than others.

The following experiment made by Ingenhausz is suitable for demonstrating the relative conductivity of different substances.

Ingenhausz's experiment—

A long copper trough has a number of holes on one side. A number of rods about 8 inches in length and made of different substances,—copper, brass, iron, glass, and wood—are first coated with a layer of paraffin wax. The rods are fitted into the holes of the trough. When the trough is filled with boiling water or oil, heat from the trough passes along the rods and melts the wax coating. The wax melts to the free end of the copper bar and this shows that copper is an excellent conductor of heat. The wax on the brass and iron rods melts to some distance away from the trough and not on the extreme end. This shows that brass and iron are not such good conductors as the copper. On the glass rod the wax melts for a very short distance showing that it is a bad conductor of heat. In the same way wood is found a bad conductor of heat.

CONVECTION

Now, heat travels through solids by conduction being passed on like waves from particles to particles of the substance, but no particles of the solid move from place to place along with the heat waves. In most liquids which are bad conductors of heat, the transmission of heat takes place in a different way : the heat is directly transferred by the motion of the hot particles of the liquid. This process is called convection. The movement of the liquid occurs for the following reason :—

If water, for instance, is heated, the portion of it near the source of heat, first gets warm and expands. As a result it becomes less dense and hence lighter than the remaining portion of water (which was not warm being away from the heat of the flame). The lighter

hot particles of water rise up and thereby carry away the heat the flame has given them. The place formerly occupied by the hot particles of water near the source of heat is invaded by the other particles of water (that were colder and heavier being away from the source of heat). These in their turn on being exposed to heat become hot and move away and let other particles of water come in to get heated. Thus the particles go on moving up and down each time getting hotter and hotter until the boiling point of water is reached.

This circulation of water called the *convection current*, goes on from below upwards and then downwards if heating is done from below. When water is heated at the top, say, in a test tube, no currents of water are started because the warm water being less dense than the cold water at the bottom of the tube does not sink but remains on the top. Further, as water is a bad conductor of heat, the heat from the top layer in absence of a current passing down, cannot pass to the bottom layer ; therefore, the water at the bottom of the tube is not warm.

The convection current in water can easily be demonstrated if sawdust or corks be added to water, and the water is heated in a flask or a beaker by a spirit lamp or gas, from below. The sawdust moves along with the current of water which passes up the hot zone and down the cold sides of the beaker.

It may be noted that as the water is warmed, tiny bubbles rise to the surface. These are the bubbles of air dissolved in water. As the temperature of water is raised, the dissolved air gets warm, expands and rises up being lighter than the water and finally escapes into the atmospheric air. The water is thus freed from air and tastes 'flat'.

As water reaches the boiling point, it is converted into steam and does not get hotter. The steam rises up

from the bottom in the form of bubbles, but before the bubbles of steam can reach the top, they break producing the well-known sound called "singing". The steam escapes into the surrounding air.

As in liquids so in gases, heat is transmitted by convection currents. Air, for example, expands on being heated, becomes lighter and rises up. Cold air is heavier than the hot air and falls down pushing up the hot air which is less dense. This is the reason why the hot air rises up to the ceiling in a room or passes up through the chimney carrying away the smoke and heat when a fire is lit in the room. We can also understand from this, how heat starts moving air and gives rise to the blowing of wind. This heat comes from the sun, and air being heated expands producing a convection current similar to that in a liquid.

Ventilation—

We need plenty of fresh air. The room feels stuffy and hot if it is over-crowded or if there is no flow of fresh air from outside. Now we have learnt that warm air rises up, and cold air passes in from below. We can use this knowledge in maintaining a fresh supply of air in a room by having windows or outlets on the top for the escape of the hot air from the room, and windows on the bottom for the incoming of fresh cold air from outside. It is a good plan to have windows on opposite walls so as to maintain a steady current of air in the room.

Radiation—

We have learnt so far that heat can be transmitted by conduction and by convection. In both cases, the transmission takes place through the agency of matter or particles of a material thing. There is another method of transmission of heat in which the presence of matter is

not needed, heat in a peculiar way passing through empty spaces. This process is called radiation. The empty spaces are not considered to be absolutely empty but are supposed to be filled with ether. *Ether* is altogether different in nature from an ordinary substance or matter, but what it really is no one knows ; it is invisible and is assumed to be present everywhere in all substances and even in vacuums. The sun is thousands of miles away from the earth, and since air does not go up beyond two hundred miles of the earth, the long intervening space between the earth and the sun is empty and is supposed to be filled with ether. Ether transmits the solar heat to the earth by radiation without itself being heated.

The heat received by the earth from the sun by radiation makes the earth hot. The earth in turn gives out by radiation much of the heat absorbed from the sun to the surrounding space and so gets cooler at night.

In radiation, heat is not transported by air or any other matter. That is the reason why one feels hot when standing in front of a fire even if a draught of air proceeds towards the direction of the fire and away from the observer. The radiation of heat takes place independent of air currents or ordinary matter.

The invisible radiant heat travels in straight lines and is quickly absorbed by dark bodies such as lamp-black. The light coloured substances, however, reflect the radiant heat energy and do not absorb much of the heat falling on them.

When we hold an umbrella over us on a hot day, heat radiating from the sun is stopped by the dark cloth which absorbs heat. If it were air that carried this heat, the putting up of the umbrella would make very little difference in shielding us from the hot sun. For the same reason when one stands in front of a fire behind somebody he does not get the warmth of the fire, being screened

by the man in front of him. The transmission of heat by radiation is quite different from the process of conduction or convection and is the most important of the three in as much as heat passes out from a hot body in spite of it not being in contact with any other material.

Questions

1. Describe what happens when water starts boiling.
2. Explain what you understand by good and bad conductors of heat.
3. How is heat transferred by air ?
4. State the difference between convection and radiation.

CHAPTER VI

LIGHT

Light is a form of energy travelling through ether and perceptible to our eyes. The sun and the lamp emit light. They are the sources of light and are known as luminous bodies. A large number of objects is not alight but they are visible because light falling on them from a luminous source turns and reaches our eyes. In a dimly lit room the dark bodies are not visible because they do not scatter light (which falls on them from the lamp).

A stone or brick does not allow light to pass through it. Such as object is said to be *opaque*. While objects such as glass, air or a thin layer of water allowing the passage of light through them, are known as *transparent media.* Ground glass allow light to pass through it, but objects are not clearly visible through it. It is called *translucent.*

RECTILINEAL PROPAGATION OF LIGHT

A luminous body such as the sun, a lamp or a burning candle, emits light from all its points, and the light from each point travels in a straight line. We can only see objects which fall in a straight line with our eyes and cannot see objects which are situated at a bend from our point of vision. Light does not bend round the corners of a building but casts shadows if intercepted by an opaque object.

Any one of the straight lines from a source of illumination is called a ray of light, and a bundle of rays is known as a pencil of rays.

The rectilineal propagation of light which means travelling of light in straight lines can be proved from the following simple experiments :—

(*i*) A large cardboard is placed in a dark room between a screen and a lamp in such a way that the light from the lamp falls on the screen through a pin-hole made in the cardboard. An image of the lamp is seen on the screen. By varying the distance between the screen and the cardboard, the image can be made sharp. The image of the lamp thrown on the screen is inverted. This can be explained if light from the flame passes in a straight line through the pin-hole. The ray of light from the top point of the flame passes through the hole slanting down and forms the lower point of the image, while the ray from the lower point of the flame in reaching

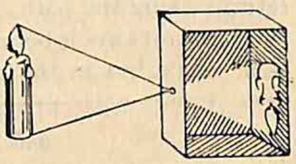

Fig. 18. Image formed by a pin-hole

the screen through the pin-hole, follows an upward course and forms the highest point of the image. The paths followed are in straight lines which cross at the pin-hole as shown in figure 18.

(*ii*) If the sunlight is admitted into a darkened room through a narrow slit in the window, the dust particles hanging in the air are illuminated and the straight path followed by the rays is easily seen. It may be noticed that the image of the sun falls on the floor of the room but if a screen is held near the hole to receive the image the latter has the shape of the slit and not of the sun.

(*iii*) The rays of sunlight breaking through clouds also show the passage of light in straight lines.

REFLECTION OF LIGHT

A moving ball striking against a wall or a plane surface rebounds. If it strikes perpendicular to the surface, it returns along the path it followed. If the ball strikes the surface slantways it bounces off the surface slantways at the same angle but in the opposite direction. The perpendicular to the reflecting surface is known as the *normal*. The angle which the path makes with the normal is called the angle of *incidence*, and the angle which it makes with the normal in rebounding, is known as the angle of *reflection*. The two angles are equal.

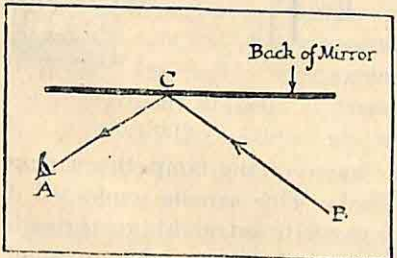

Fig. 19. Reflection by a plane mirror
B—Incident ray
A—Reflected ray
C—The point where the ray strikes the polished surface of the mirror

A beam of light behaves like an elastic ball when it falls on a polished surface (Fig. 19). It turns, the angle of incidence being equal to the angle of reflection.

Reflection by a plane mirror—

In a plane mirror which is made of a plane glass silvered at the back, the rays falling on it, are reflected; and we see an image of the object by the reflected pencil of rays entering our eyes. This image is formed behind the mirror and is of the same size as the object. The image stands behind the mirror erect, and at a distance from the mirror equal to that between the object and the reflecting surface of the mirror. This image is of a different type from that formed by a beam of light passing directly through a pin-hole in a darkened room. It cannot be thrown on a screen. It is called the *virtual* image as opposed to the *real* image. The pencil of rays entering the eyes seems to proceed from the image, but really none of the rays is coming from the image. But if the rays from the object were to be produced behind the mirror they would form a cone of rays which meet where the image was formed.

The path followed by the reflected ray depends on the angle the incident ray makes with the reflecting surface or rather with its normal.

If we examine the image formed by a plane mirror such as our ordinary looking-glass and compare it with the object we find that it has suffered a lateral inversion. Our right hand before a mirror is seen as the left hand of the image.

Letters written in ink and pressed against a sheet of blotting paper while wet, are found inverted on the blotting paper. If the blotting paper with the writing impressed on it, is held before a mirror the letters become legible.

A multiple number of images of a single object can be formed by placing the object in between two plane mirrors.

The image formed by the first mirror acts like a source of light or a real object and is reflected by the second mirror, and the image formed by the second mirror acts like a real object and is reflected by the first mirror and so on.

If a reflecting mirror is rotated the reflected ray is turned through an angle which is twice as large as the angle of rotation of the mirror. This principle is used in the design of optical instruments such as the sextant for finding out angular distances of objects.

Reflection by spherical mirrors—

Spherical mirrors have the reflecting surface in the form of a curve and form a small part of a sphere. Such mirrors are either concave or convex. The concave mirror (Fig. 20) has the reflecting surface in the form of a depression facing the source of light or an object. In a convex mirror the depression is on the opposite side of the reflecting surface. Various types of images are formed by them. They are virtual or real, magnified or diminished in size. Our face looked through a spherical mirror appears distorted.

If a beam of light is thrown from a great distance on a concave mirror, the rays after reflection converge to a point, which is on the same side of the mirror as the object. The point represents the focus of the mirror. The distance between this point and the centre of the reflecting surface, is known as the focal length of the mirror, and it is half of the radius of a sphere of which the concave mirror forms only a part. If the source of light is placed at the focus of the mirror, the rays of light falling on the mirror are reflected to form parallel beams of light.

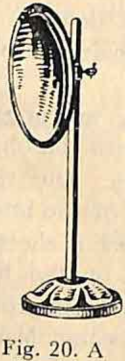

Fig. 20. A Concave mirror

The reflector placed at the back of a

cycle or motor lamp, is a concave mirror and it strengthens light by turning it forward.

If you put your face close to a concave mirror, it will be noticed that a magnified image of the face is seen further away from the mirror. The image is erect and virtual. As you move away from the mirror, the image comes closer to the mirror. If the distance is further increased, an image is formed which is inverted and is smaller in size. This image can be received on a screen and is known as the real image.

If a convex mirror is taken, it will be found that for all positions of an object before the mirror, a virtual, erect, and diminished image is seen.

REFRACTION

Refraction means breaking, and in physics, it means bending of a ray of light as it passes on from one medium to another. When a ray of light travelling through air obliquely falls on water, the direction of the ray is changed by the bending or refraction. The ray passing through water is the refracted ray.

If a normal be drawn to the surface of water, it will be found that the angle which the incident ray makes with the normal, is greater than the angle which the refracted ray makes with the normal. This is because the refracted ray lies close to the normal, while the ray travelling through air and striking the surface of water, namely, the incident ray, is away from the normal. The degree of bending or deflection of the ray is influenced by the difference in the density of the two media, namely, air and water. The ray in travelling from air to water, is passing from a rarer to a denser medium, and the bending takes place at the surface where the two media meet.

When a ray of light passes out from water to air, the emergent ray bends at the bounding surface and is away from the normal.

Owing to the refraction, an object immersed in water appears as raised nearer to the upper surface of water. The object appears to be at the place where the pencil of rays from the eye would converge if produced beyond the limiting surface (Fig. 21).

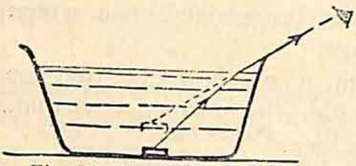

Fig. 21. The raising of a coin by refraction

Put a coin at the bottom of a bowl. Place the eye in such a way that the coin just lies hidden below the upper edge of the bowl. Put some water into the bowl, the coin now becomes visible (Fig. 21). The light from the coin passing out of the water is bent so as to reach the eyes. Had there been no refraction, the rays from the object could not have reached the eyes.

Place a stick obliquely in a vessel so that a part of it

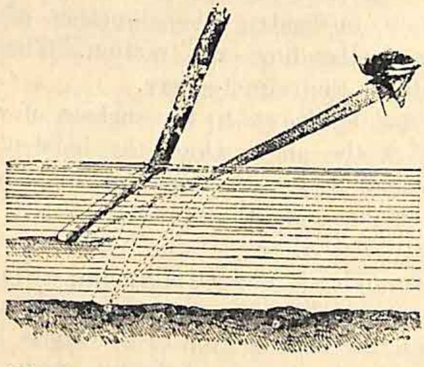

Fig. 22. Bending of a stick by refraction

is under water, and a part of it in air above the water (Fig. 22). Look at it sideways. The stick appears bent

just where it enters the surface of water, and the part under water appears higher than it really is. This is owing to refraction of the light rays.

A pool of water appears shallower than it really is, owing to the refraction of light rays passing up from the water below to the air above.

Refraction through prism and lens—

Refraction also takes place when a ray of light passes from air to glass. If a slab of glass be taken with flat and parallel surface, a ray of light falling obliquely on a side of the glass, bends on striking the surface of the glass and then passes straight through it. On reaching the opposite side of the glass, the ray bends again as it comes out into the air.

The ray has therefore suffered refraction twice, once when it entered the glass, again as it emerged from the glass. Since the second deviation of the ray is equal in degree to the first but in opposite direction, the incident ray does not coincide with the emergent ray but the two run parallel to each other, the two sides of the glass being parallel.

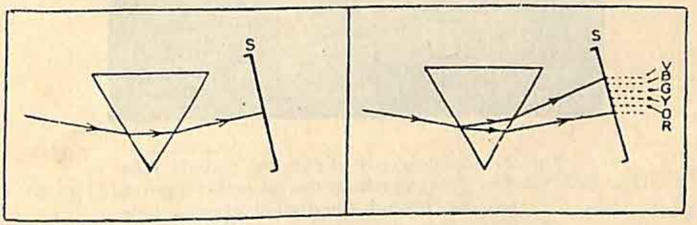

Fig. 23. Refraction by a prism
S—The screen on which the band of colours, violet to the red, is seen due to the separation of the sunlight by prism. The left hand figure shows the bending of ray by the prism

A prism is composed of a glass cut pyramidal in shape. Since the two surfaces concerned with the deviation of a ray, are inclined to each other, the emergent ray is bent towards the base of the prism (Fig. 23).

Rays passing through a lens suffer refraction as in the prism the emergent ray bending towards the thick portion of the glass. The image formed by a lens depends on the shape and curvature of the lens. Lenses may be double convex and double concave or of any other form.

A double convex lens in thick in the middle. If two prisms be joined by their bases we get a near approach to the double convex lens. The ray entering the convex lens is bent as twice in the prism, and as it comes out it is seen drawn towards the axis of the lens. The axis passes through the centre of the lens.

A parallel beam of light after passing through the convex lens converges on the opposite side to a point which is called the focus of the lens (Fig. 24). The distance between the focus and the centre of the lens, is

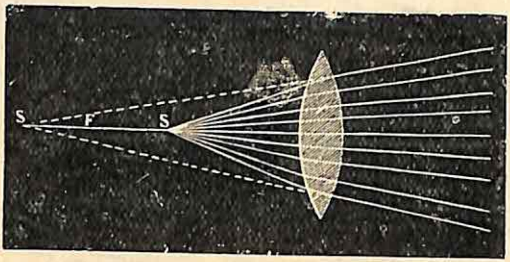

Fig. 24. Convergence of rays by convex lens
S—The point to which the rays converge on passing through the double convex lens
S—The point where the rays would meet if continued straight
F—Focus

called the focal length. If the convex lens be held near a white surface of a wall, an image of a distant object will be found on the screen or on the wall. This image is made sharply defined by adjusting the distance between the lens and the screen. The image will be found inverted

and reduced in size. It is the real image. So long as the object is kept beyond a distance greater than the focal length of the lens, real images will be formed on the screen. This occurs because the rays on passing through the lens are drawn closer (by bending towards the thicker part of the lens) and converge to a point. Virtual images are formed if the object is put very near the lens.

A double concave lens is scooped out on both the sides, and is thin in the middle. Rays passing through it bend towards the thick ends which correspond to the bases or prisms (Fig. 25). Rays of light therefore on

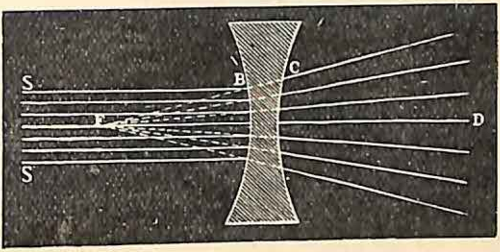

Fig. 25. Divergence of rays by concave lens
S—S—Parallel ray falling on the double concave lens
B—C—The path of a ray diverging on the side D
F—Focus

passing through the lens, move away from the axis of the lens. Rays thus diverge by refraction through a concave lens. Virtual images are formed.

In a camera the image of an object which is to be photographed is thrown on a screen behind the camera by the aid of a convex lens placed at the front part of the camera. As the distance of the object varies and the screen is fixed, focussing, that is, throwing a sharp and distinct image on the screen, is done by moving in or out the lens.

4

In a human eye there is a lens in the front part of the eye which projects the image of objects on the retina which acts like a screen in the camera.

People who have defective eyes cannot focus light on the retina and require extra lenses in the shape of spectacles. If they are long-sighted it means that the light from a near object is focussed behind the retina and thereby no sharp images can be formed on the retina. In such cases an extra convex lens is required in the spectacles to bring the rays to the retina by converging them. If people are short-sighted, images are formed in front of the retina and a concave lens is required in the spectacles so as to open out the rays and push back the image a little.

Propagation of waves—

If a stone is thrown in the calm water of a pond, ripples or waves are formed which spread in concentric circles from the centre of the disturbances. Particles of water move up and down, and this motion is transmitted to other particles next to them. As the waves travel, the water particles are not carried away with them from the centre of the disturbance to the periphery but are vibrant, rising with the crest and falling with the depression.

If a long rope is thrown into undulations, the undulations or waves pass on from one end to the other. The distance between two successive undulations gives the length of a wave.

Light is supposed to travel in the form of waves set up in the ether. Since ether pervades everywhere, light waves pass through air and water. They travel with a tremendous velocity of 186,000 miles per second, and are faster than the fastest aeroplane. It is for this reason that light is seen as soon as a lamp is lit. Where, however, the light has to traverse an immense distance as between the

earth and the sun, it takes some time before light can pass from the source to an observer. Light from the sun takes nearly 8 minutes to reach the earth.

Questions

1. How would you demonstrate that light travels in straight lines ?
2. State the difference between shadows and images.
3. Explain why a polished surface shines in light.
4. Explain the phenomenon of refraction.

CHAPTER VII

COLOURS

SPECTRUM

In a darkened room if a beam of sunlight is admitted through a narrow slit of window and is allowed to pass through a glass prism so as to fall on a screen, a band of colours is seen projected on the screen (Fig. 23). The colours range from violet, blue, green to yellow, orange and red. If the beam of light is focussed on the screen by means of a convex lens, and the prism interposed between the screen and the lens is turned, it is found that for a certain position of the prism, the band of colours on the screen becomes sharp and vivid (Fig. 26). The band of colours seen on the screen is called a spectrum.

The white light of the sun on passing through the colourless prism, separates into the colours of the spectrum. These colours are actually in the sunlight all the time and not on the screen or the prism, but we cannot see them until they are sorted out by some such means as placing a prism in the path of the sun's rays.

The sunlight consists of a mixture of these coloured lights and the white light or rather the colourless light of the sun is the combined effect of the colours ranging from violet to red. This is proved if the coloured lights on being recompounded give rise to white light. The recompounding can be done by reversing a prism and placing it in the path of the coloured lights emerging from the first prism. The white light is formed again.

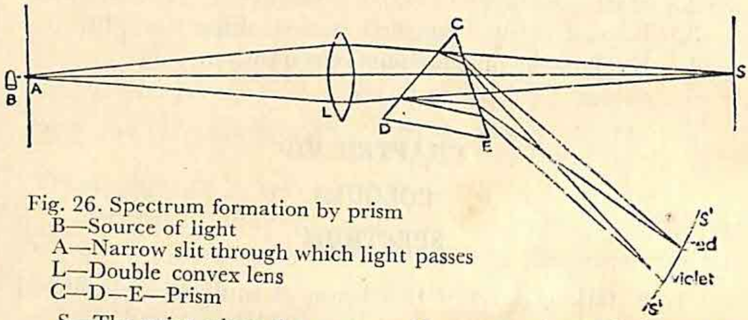

Fig. 26. Spectrum formation by prism
B—Source of light
A—Narrow slit through which light passes
L—Double convex lens
C—D—E—Prism
S—The point where the rays would converge if not deviated by the prism
S′S′—The screen receiving the spectrum colours ranging from red to violet

If a circular disc of cardboard be divided into six equal sectors and the sectors be painted respectively with violet, blue, green, yellow, orange and red colours and the disc is rotated very fast, the six colours would not be seen but the cardboard would seem grey or white in colour. As the coloured disc moves very fast, the impression of one colour on the retina overlaps the succeeding one and leads to the blending of colour. The eye gets therefore the impression of a white light.

The separation of the white light into coloured lights by the prism can be explained in the following way.

The white light is produced by the blending of the coloured lights which have different wave lengths. In other

words, the sunlight consists of ether waves of various lengths. The violet and blue lights have shorter wave lengths while red has the longest wave length. When light passes through a glass prism, the shorter ether waves are bent more than the longer ones, hence the rays instead of falling on one spot all mixed together, fall on separate spots on the screen, the longest waves following one path, the shortest waves another path and the intermediate ones situated between the two extremes. The prism therefore by refraction bends or deflects the rays of light passing through it to different degrees and thus causes the separation of the mixed lights into its constituent rays, the short violet rays being bent more than the long red rays.

The beautiful rainbow with orange, yellow and blue margins seen at certain times in the sky with our back to the sun, or the rainbow colours when the sun shines through drops of water, are partly due to the refraction and reflection of the light by drops of water. A ray of light entering at a spherical drop of water bends by refraction and then passes through it, and on reaching the opposite surface of the drop, is reflected and thereby suffers a change in direction. The reflected ray in emerging from the drop of water again suffers refraction giving rise to the colours of the spectrum.

We also find a play of coloured lights when the sun shines through a film of soap bubble or when a thin film of oil spreads over water. The colours seen came from the white light of the sun and not from the soap or the oil.

Now, if copper sulphate, or copper be heated in a flame, the flame is tinged greenish. Similarly, potassium gives a violet light, and sodium a yellow light. In each case a mono-coloured light is obtained. If a yellow light is made by adding the common table salt which contains sodium, to the flame, and this light is allowed to pass through a glass

prism, a spectrum is obtained which is different from that of the sunlight. It lacks in red, green, blue and violet colours which are present in the solar spectrum.

Each substance produces its own special light and by the analysis of the spectrum, a scientist can identify an unknown substance in the same way as a man is identified by his finger print. The different colours seen in the spectrum of the sunlight therefore give a clue as to the substances present in the sun.

Now when sunlight passes through a red glass, all the light is changed red. This is because all the lights except the red have been absorbed by the red glass, and the red only has been allowed to pass through it as a favourite. A book bound with red cloth absorbs all the rays except the red which reaches our eyes. A black cloth absorbs all the coloured lights present in the sunlight and appears therefore dark.

It has been found that every colour can be produced by mixing in various proportions, the red, green and blue colours of the spectrum. These three colours are known as the *primary colours*.

If we mix blue paint with yellow paint, we get green colour. Blue and yellow lights, however, when mixed together form white. Two colours are said to be *complementary* when together they form white light. Blue and yellow are complementary; so are red and green.

Questions

1. What is a spectrum?
2. How can you split up the sunlight into coloured lights?
3. Why is a coloured thing seen of a different hue when examined in a gaslight?

CHAPTER VIII

MAGNETISM

Lodestone—

The lodestone is found in the form of a black stone in several parts of the world such as Asia minor, Norway and Sweden. It is a natural magnet. It attracts small pieces of iron and iron filings which cling to the two ends of the magnet (Fig. 28). When suspended in the middle by means of unspun silk, it turns so as to come to a definite position in reference to the meridian of the earth, always pointing the north and the south. It was called lodestone, or "leading-stone".

Artificial magnets—

Magnets are now artificially made. The steel rod or a needle to be made into a magnet is placed horizontally on a table and is repeatedly rubbed with by one end of a lodestone or a magnet. The stroke should be drawn from one end to the other of the object to be magnetized. There are different other ways of making a magnet, say by touch with a magnet or by sending a current of electricity round the iron or a steel piece.

There are various forms of magnets (Fig. 27). The bar magnet has the form of flat piece of steel, and the horseshoe magnet is U-shaped. The compass needle consists of a magnetic needle which is pivoted in the centre. A mariner's compass in its simplest form consists of a small magnetized needle which is supported on a pivot placed at the centre of a cardboard which is marked North and South, East and West.

Iron, steel, nickel are attracted by a magnet and also can be turned into a magnet. They are called *magnetic substances*. Soft iron acquires magnetic property more easily than steel. It develops into a magnet when placed

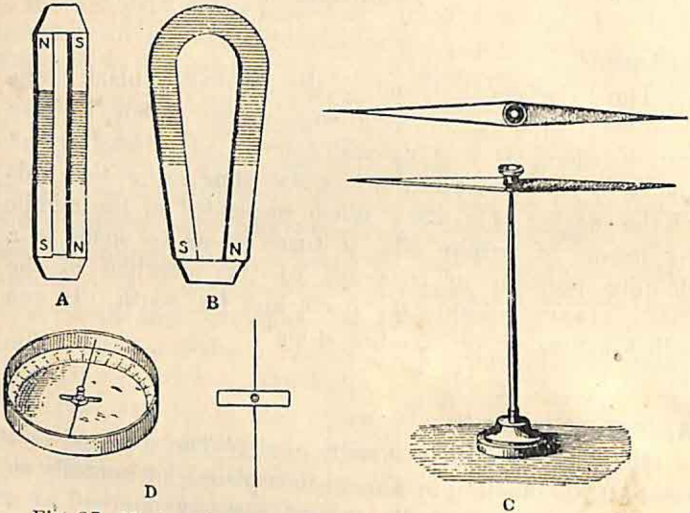

Fig. 27. Various forms of magnets
A—Two bar magnets
N—North pole
S—South pole
B—Horse-shoe magnet
Note the piece of soft iron placed as a *keeper* over the ends of the magnets
C—Magnetic needle
D—Magnetic compass

near a magnet. Soft iron, however, easily loses its magnetic property. Steel retains magnetization much better. A magnet loses its magnetic property if roughly handled or passed over a flame and then it is said to be demagnetized.

Other substances such as copper, gold, wood or paper are neither attracted by a magnet nor can be made into a magnet. They are called *non-magnetic substances*.

Properties of a magnet—

If a magnet is suspended by means of a thread or is pivoted in the centre so that it is free to move in a horizontal direction, it sets itself to coincide nearly with the meridian of the earth, its two ends pointing towards the north and the south. The two extreme ends of a magnet are called its *poles*. The end directed towards the north is called the north-seeking pole or in brief the north pole of the magnet. It is often marked "N" on the magnet or is coloured red. The opposite end directed towards the south is called the south pole of the magnet. If either of a pole of a magnet be dipped in iron filings, the latter cling to it (Fig. 28). But the middle portion of a magnet does not attract the iron filings and this may be called the *neutral zone*. If, however, a magnet is broken into small pieces, one end of each broken piece behaves like a north pole and the opposite end like a south pole. Both the ends of a broken piece attract iron filings, the central portion remaining neutral. A magnet attracts another magnet or repels it (Fig. 29). The laws of magnetic attraction and repulsion are as follows :—

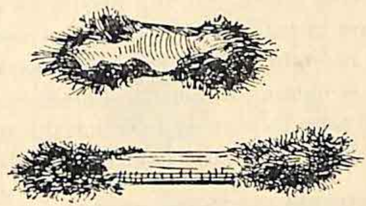

Fig 28. Iron filings attracted by the poles of a magnet

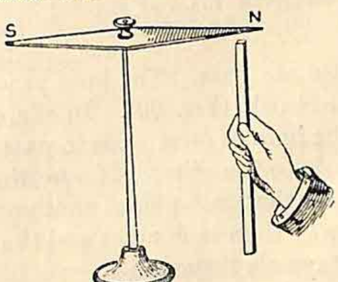

Fig. 29. Action of one magnetic pole on another

If the south pole of a magnetic needle or of any other magnet be presented to the north pole of

another magnet, the two opposite poles are attracted to each other. Attraction occurs whenever two dissimilar poles are brought nearer.

If the north pole of a bar magnet be presented to the north pole of a compass needle the latter turns away being repelled by it. The repulsion equally occurs whenever two south poles are brought near each other.

The rule is *like poles repel* and *unlike poles attract*.

Magnetic field—

If a compass needle be brought close to magnet the needle turns. If the needle be placed at a great distance from a magnet, the compass needle is not affected. As it is brought nearer it is found by turning of the needle, that it is coming under the influence of the magnet. The space all round a magnet in which this magnetic influence is noticeable is called the field of a magnet. The magnetic field is permeated by invisible lines called the lines of force. The direction of these lines of force can be mapped. If a glass plate be placed over a bar magnet and iron filings are spread over the glass, it is found by tapping the glass that the iron filings arrange themselves in definite lines. The lines proceed from each pole diverging outwards (Fig. 30). In the case of a Horse-shoe magnet, the lines of force seem to pass in concentric circles from one pole to the other. If a north pole of a bar magnet be held near the north pole of another magnet the lines of force bend away from each other and the two poles are repelled.

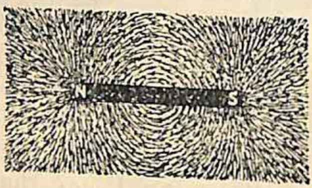

Fig. 30. Lines of force of a bar magnet

Magnetic induction—

Iron or steel gets magnetized when brought in contact with the pole of a magnet. The end of an iron or steel

rod which is in touch with the north pole of a magnet behaves like the south pole, and its other end far away from the magnet behaves like the north pole. In view of this opposite polarity induced a long chain of iron nails or needles can be held by the pole of a magnet, each link in the chain acts like a magnet holding the one next to it (Fig. 31).

An iron rod develops magnetization even if it is not in direct contact with a magnet, but is held near it or brought within the magnetic field. The lines of force permeating the magnetic field enter it and the magnetic property is induced.

If a piece of iron rod be placed within a glass tube the glass tube is held by the pole of a magnet, the rod inside being magnetized by induction.

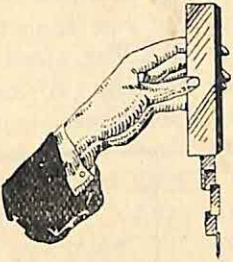

Fig. 31. Nails held by induced magnetism

The earth as a huge magnet—

The earth behaves as if it had a large magnet hidden in its interior, influencing all magnets or magnetic substances. The reason why a magnetic needle turns towards the north and the south pole of the earth is understood if we assume the earth to be a huge magnet. A magnetic substance if placed for a long time along the magnetic meridian gets magnetized.

Questions

1. How are artificial magnets made ?
2. Why is a soft iron attracted by a magnet ?
3. How would you know whether a piece of iron is magnetized or not ?
4. What do you understand by magnetic properties ?
5. State what happens when the north pole of a magnet is presented to the north pole of a compass needle.

CHAPTER IX

ELECTRICITY

Voltaic Cell—

If a zinc and a copper plate be immersed in dilute sulphuric acid (say, 10 parts of water and 1 part of acid) contained in a glass jar, and the two plates are joined above by a copper wire, a current of electricity flows along the wire from the copper plate to the zinc plate (Fig. 32). The wire is fixed to the top of the respective plate by means of a binding screw which may be considered as the terminal of that plate.

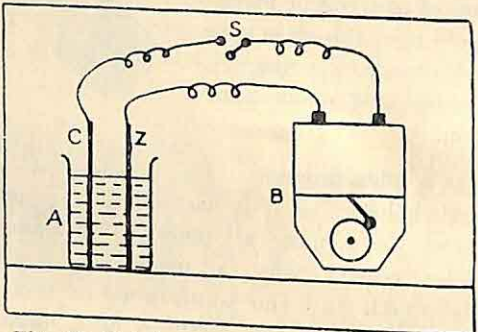

Fig. 32. Voltaic cell

A—A beaker containing dilute sulphuric acid
C—A plate of copper
Z—A plate of zinc
S—A switch
B—A current indicator

Sulphuric acid acts on zinc producing bubbles of hydrogen gas which as soon as the two plates are connected by the wire, stream through the acid bath and are deposited on the opposite copper plate. The zinc

plate is gradually eaten up by the acid. The electric energy is generated by this chemical action.

The electric current flows through the bath from the zinc to the copper plate, therefore it is opposite to that passing through the wire. The current of electricity along the wire flows from the terminal of the copper plate to the terminal of the zinc plate.

The above apparatus generates electricity and it is known as a simple voltaic cell.

The electricity flowing through the wire can be compared to the flow of water through a pipe with this difference that the electric wire is not hollow and the flow of electricity cannot be seen. Now, water flows through pipes from a high level to a low level. The electric current is also flowing from the copper plate through the wire to the zinc plate. Therefore the copper plate is considered to be at a higher level than the zinc plate and the flow of electricity is maintained by this difference in the levels. The copper terminal is known as the *positive pole* and the zinc the *negative pole*. The difference of levels in electricity is called the *potential difference*.

The wire joining the terminals offers resistance to the flow of the current; the resistance is overcome by the force caused by the potential difference called the *electro-motive force* or e.m.f. This is expressed in terms of *volts*, and the resistance in *ohms*. The current is measured in units called *amperes*.

There are various other types of cells for generating electricity. A few types of these are given below :—

Daniell's Cell—

It consists of a glass vessel which contains dilute sulphuric acid. A zinc plate is dipped into it. In the centre of the vessel a porous pot is put. The pot is filled with

copper sulphate and a copper plate is put in it. Copper is the positive and zinc is the negative pole; a current of electricity flows when the plates are connected by a wire. The potential difference of the cell is nearly one volt.

Leclanche´ Cell—

In this cell a carbon plate is placed within a porous earthen pot which is closely packed with carbon and black oxide of manganese. The pot containing the carbon

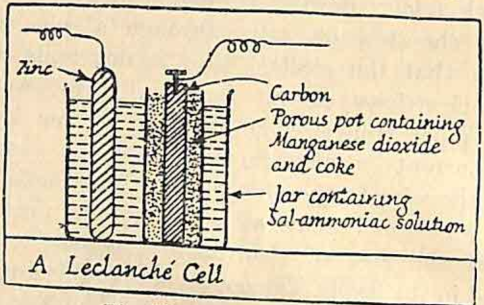

Fig. 33. Leclanché Cell

plate is placed within a solution of salammoniac (Ammonium chloride) contained in a glass vessel. A zinc rod is immersed in this solution (Fig. 33).

Battery—

When a stronger current is necessary this can be obtained by joining two or more cells. A group of cells is called a *battery*. The cells can be joined in two ways. When the positive terminal of one is connected with the negative terminal of the next, the cells are said to be joined in series. Cells combined in this way raise the potential difference. If the positive terminals or poles and joined together and the negative terminals are similarly joined they are said to be in parallel.

Conductors and Insulators—

Electricity flows through certain substances which are called *conductors* ; while it will not pass through others which are, therefore, called *non-conductors* or *insulators*. All metals are conductors and offer least resistance to the passage of electricity. Copper is a better conductor than iron and hence copper wires are used for leading electricity from one place to another. A wire having a large cross-section offers less resistance to the passage of electricity through it than the one having a narrow cross-section.

Electricity seeks the path of least resistance ; therefore if a wire leading a current of electricity touches a wall of a house, the electricity flows along the wall which offers to it a wider passage. But it cannot escape from the wire if the latter comes in contact with a non-conductor.

The wires used in electric work are generally covered with non-conducting materials such as cotton, silk, gutta-percha. Such wires covered with a non-conducting coat are called insulated wires and the non-conducting substances are known as insulators. The insulators offer a very high resistance to the passage of electricity and hence very little electricity can pass through them into other parts.

Questions

1. Describe a simple voltaic cell.
2. Distinguish between conductors and insulator.
3. Why are insulated wires used for leading electricity ?

CHAPTER X

EFFECTS OF ELECTRICITY

When electricity passes through a body, heating, lighting, magnetic and chemical effects are produced.

Heating effect—

A wire or a conducting material carrying electricity gets hotter. The heat generated in a wire by the passage of electricity may be so great that the wire may melt. The heat is caused by the changing of electrical energy into heat energy and this occurs if the conducting wire offers increased resistance to the current passing through it. Very little heat is generated in wires which readily conduct electricity. It is for this reason that the radiators for heating purposes, are not made of copper which is a good conductor, but are made of an alloy of nickel and chromium. The alloy offers high resistance to the passage of electricity and the wires get red-hot.

If the temperature rises very high, the wires would melt causing a gap in the circuit. In such a case the current would cease to flow. This principle is applied in making fuse-boxes in our house-wiring. Small pieces of wires called fuses are interposed in the circuit. When a strong current of electricity flows through the fuses the latter melt, and the current stops. The fuses are inserted in the circuit to stop the current if it becomes too strong. Now the current suddenly becomes stronger for various reasons. Often it may happen that the insulated coating of a wire has been damaged, and the bare wire is exposed. If the bare wire touches the wall of the house or any other conducting material, the current flows through the new circuit which offers easier path than the old circuit. The current is then said

to be *short-circuited.* A short circuit may cause the current in a wire to be two hundred times stronger. A fuse-box is necessary to check the flow of a too strong current as otherwise the wiring system may burn and set fire to the wood work near it.

Lighting effect—

Now the other effect of electricity is to produce light. If a wire through which a current of electricity is flowing, is made to offer a great resistance, the electrical energy instead of developing into heat energy, changes into light energy. A conducting wire if it is made extremely thin being drawn out in the form of a thread or filament, the resistance increases and the electricity manifests itself into light energy.

Electric lamps are made on this principle. An electric lamp consists of very thin wires made of metal or carbon and enclosed in a glass bulb from which air has been drawn out.

Magnetic effect—

If a wire through which a current of electricity is passing, be held above and parallel to a compass needle,

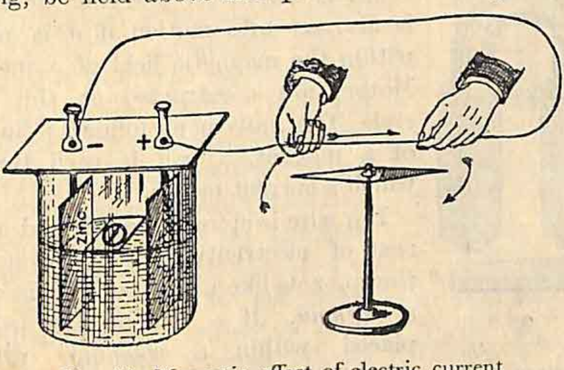

Fig. 34. Magnetic effect of electric current

the latter is turned towards the left (Fig. 34). If the wire be held below and parallel to the needle it is deflected

towards the right. The wire carrying the electricity is behaving like a magnet in deflecting the magnetic needle. The deflection is stronger if a coil of wire be wound round the compass needle without touching it and a current is sent through the wire. By this arrangement even a feeble current would set the magnetic needle turning. Galvanometers for detection and measurement of currents of electricity are made on this principle.

The direction in which the magnetic needle turns is given by the following rule. Imagine a man swimming in the direction of the current with his face towards a magnetic needle. The north pole of the needle is deflected towards his left land.

On account of the magnetic effects a wire carrying electricity also attracts or repels another conductor through which a current is passing. For instance, if two conductors are held parallel to each other and the currents flow in the same direction they are attracted by each other. They repel each other if the currents pass through them in opposite directions. A conductor carrying electricity is also set into motion if it is placed within the magnetic field of a magnet. Motors are constructed on this principle. The movement follows if instead of a magnet, a coil is used through which a current passes.

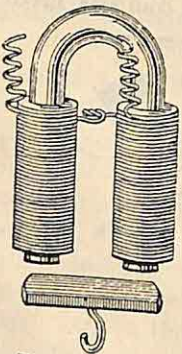

Fig. 35. An electromagnet

If a wire is spirally coiled and a current of electricity is sent through it, the coil acts like a magnet and is called a *solenoid*. If a rod of soft iron be placed within a solenoid, without touching it the rod becomes magnetized by induction. The whole acts as a powerful magnet. Electromagnets are made on this principle. Insulated wires

are closely wound round an iron rod to form an electromagnet. When a current of electricity passes through the coil the iron rod becomes magnetized. As soon as the electricity ceases to flow, the rod, if it is made of a soft iron, loses its magnetism. Electromagnets (Fig. 35) are much more powerful than an ordinary magnet. If a steel or iron be held near an electromagnet it will be attracted.

Electric Bell—

In an electric bell the principal parts are the gong, the vibrating hammer and the electromagnet. The bell rings when the vibrating hammer strikes the gong. The hammer is moved by the electromagnetic effect produced by a current. On the back of the hammer is a piece of steel spring which presses lightly against an adjustable screw. The spring is connected with a rod of soft iron. The electromagnet stands in front of the iron rod (Fig. 36). The current from the terminal of a battery is led to the screw and passes through the steel spring to the base of the hammer. Thence it flows round the coils of the electromagnet to the other terminal, and the circuit is completed. As the current passes through the electromagnet the latter attracts the iron rod and pulls it towards itself: the hammer strikes

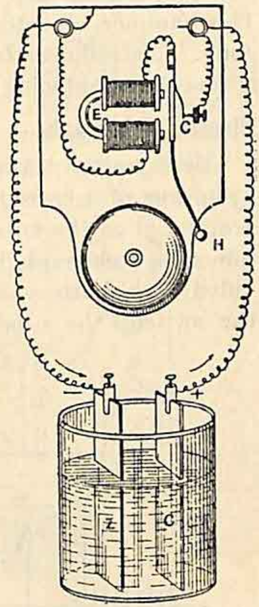

Fig. 36. An electic Bell
Z, C—Zinc and copper plates of a cell. The terminals of the cell are connected by wires to the electric bell
C—Spring connecting the adjustable screw on the right and the soft iron rod on the left
H—Vibrating hammar connected with the soft iron rod and ringing the bell
E—Electromagnet

the gong. The iron rod moves forward carrying away the steel spring from the screw. The circuit is thereby broken. The current ceases and the electromagnet no longer attracts the iron rod. The vibrating hammer springs back to its first position and touches the screw. The current starts again. The hammer vibrates and a second blow is given to the gong. Then follows a break in the circuit. The whole process is repeated producing a continuous ringing of the bell.

Electric Telegraph—

Messages are transmitted from one station to another by means of a current of electricity. Two galvanometers are placed at the two stations and are earthed. They are joined by telegraph lines (Fig. 37). Each station is pro-
vided with battery. The operator at one station moves the switch, the needle of its galvanometer is deflected.

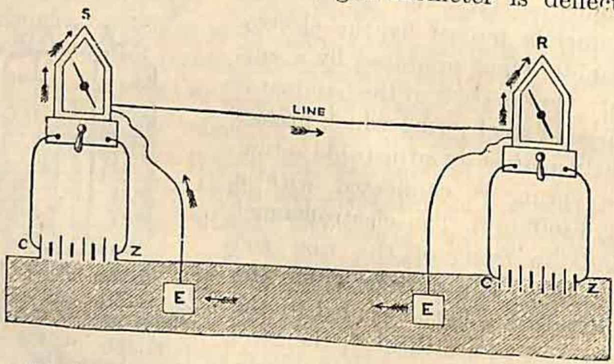

Fig. 37. Telegraphic circuit
C,Z—Electric battery at the two stations
E—Earth
S—Galvanometer at the transmitting station
R—Galvanometer at the receiving station

The current passes along the telegraph line to the other station and moves the needle of the galvanometer placed there. Different combinations of the movements of the

galvanometer needles stand for different letters. A message is transmitted by means of codes.

Induced current—

If a current of electricity passes along a wire a magnetic field is created round the wire. The magnetic field is permeated by lines of force as in a magnet. If these lines of force are cut by a second conductor, electricity is generated in the latter. It is called the induced current.

Insulated wires are closely wound to form a coil. If a magnet is moved inside the coil, a currnet is produced in the coil (Fig. 38). Instead of moving the pole of a magnet inside the coil, a second coil carrying electricity

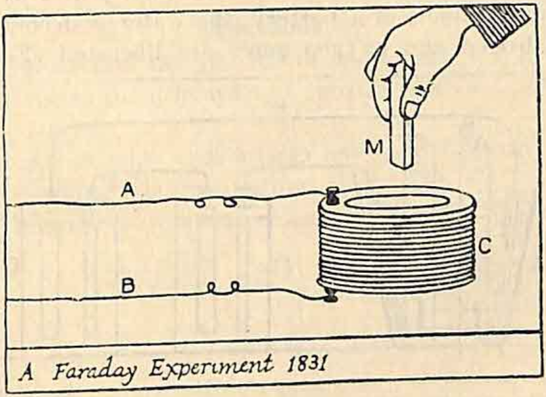

Fig. 38. Induction current
C—A coil of insulated wire connected by long wires A and B to a sensitive Galvanometer
M—Magnet which is moved in and out of the coil

may be thrust within the first coil. The effect is the same, a current of electricity is induced in the first coil. Here the current is generated not by chemical agents as in Voltaic cells but by electromagnetic induction.

The *Dynamo* is a machine for generating strong current of electricity by induction. Large coils of wire called *armature* are made to rotate between the poles of a magnet. The movement causes a current of electricity to flow in the wire of the armature. This is collected and passed into external circuit. The movement of the coil can be done by a steam engine or by a current of water which turns turbines for rotating the armature of the dynamo.

CHEMICAL EFFECTS

Electrolysis—

If a current of electricity is passed through water by immersing into it two metal plates which are joined by wires with the terminals of a battery, the water is decomposed, and hydrogen and oxygen gases are liberated (Fig. 39).

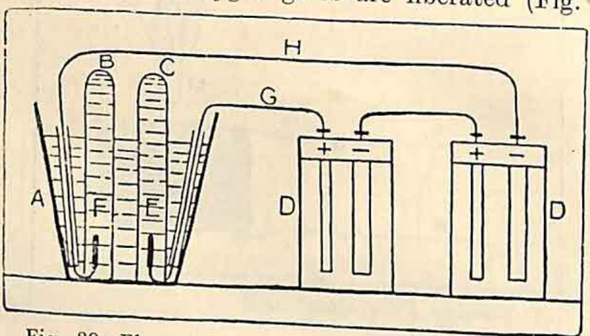

Fig. 39. Electrolysis of water.
A—Tumbler
B,C—Test-tubes containing water and provided with electrodes F and E
D—Electric battery consisting of two accumulators connected up with the electrodes by wires G and H

Dilute sulphuric acid is a good conductor and it should be added to the water to help in the passing of a current of electricity through the water from one plate to another.

The process by which the water is split up or decomposed is known as *electrolysis*. Any liquid that behaves as above is called an *electrolyte*. The minute particles liberated by the decomposition of an electrolyte are known as *ions*.

The plate by which the current enters the liquid or the electrolyte, is called the *anode* (which means a way up) and the plate by which the current leaves and returns to the battery is the *cathode* (way down).

When a current passes through a solution of metallic salts, the salts are split up and the metals are deposited as a thin layer on the cathode. Electroplating is done on this principle.

Questions

1. Enumerate the effects of electricity on a body.
2. Explain the principles of construction of an electric lamp.
3. Explain why a compass needle is deflected by a conducting wire leading electricity.
4. Describe the working of an electric bell.

PART II

CHEMISTRY

CHAPTER I

SOLUTION

When sugar is added to water we find that the sugar disappears, and the water tastes sweet. We say that sugar has passed into solution. Water is the *solvent* here and sugar the *solute.*

Water is the solvent of numerous other substances. The common table-salt and alum are soluble in water. By stirring or heating the liquid, the process of solution is quickened.

When salt and sugar are separately dissolved in water, both give a colourless solution : but the solution has the taste, or rather the property, of the substance dissolved, one having salty, the other sweet taste.

Copper sulphate which is blue in colour, dissolves in water giving a blue solution. Potassium permanganate dissolved in water, lends its pink colour to the solution, although no particle of this substance is visible in the water.

In the solution of salt in water, we can also dissolve sugar. This solution has the taste of both salt and sugar. But such is not the case if the two substances dissolved in the same liquid act chemically upon each other, and a new substance is formed.

It may be observed that as we make a solution of a solid, say, sugar or salt, in water, there occurs no appreciable change in the volume of water, but a distinct increase in weight of the solution is noticeable in proportion to the amount of the substance dissolved.

The solid substance dissolved can be recovered from the solution by evaporating the solvent. Boil a solution of salt in a porcelain basin on a tripod stand and wire gauze. After the water has completely evaporated the salt is found remaining in the basin.

Substances which are insoluble in one liquid may be soluble in another. Thus sulphur is insoluble in water, but is soluble in carbon disulphide. Rubber is insoluble in water but soluble in ether. Shellac is soluble in methylated spirit and turpentine, but not in water.

One liquid may dissolve another liquid. But oil and water do not dissolve each other. When mixed, one floats on the other.

Liquids can dissolve gases also. Thus air is soluble in water, and, as the water boils, the dissolved air is disengaged from the solution and escapes as bubbles.

Separation of mixtures—

We can separate solid objects when they are mixed together by hand and can even pick up the particles if they are of convenient size. If sand and large stone chips be mixed together we separate them by passing the mixture through a sieve which allows the sand particles to pass through but holds back the larger stone chips. By winnowing we remove husks from grains the former being lighter than the latter.

If sand and iron filings be mixed together, they can be separated by holding a magnet over them. The iron filings are attracted by the magnet, while sand remains behind.

Decantation—

If sand is mixed with water, it can be separated from the latter by allowing the sand to settle down and then pouring out the water. This process is known as

decantation and the water poured into another vessel is the decanted fluid.

Filtration—

Decantation is not a very satisfactory method of separating an insoluble solid from a liquid because the finer grains of the solid may pass out with the liquid. A better method of separation is to pass the mixture through a filter or porous material which will allow the liquid to trickle through but will hold back the suspended matter.

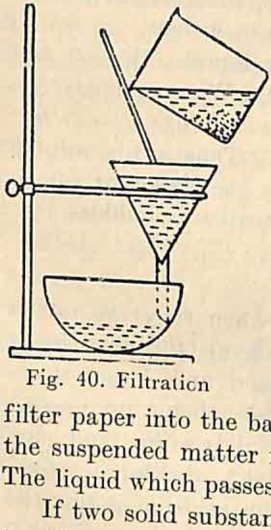

Fig. 40. Filtration

Take a circular filter paper and fold it into halves, and then into quarters. Then open the paper out so as to form a cone. Fit this paper cone into a funnel and arrange the apparatus as in the figure (Fig. 40). Pour the liquid, say, water containing suspended particles of sand or clay into the funnel. Clear water trickles down through the filter paper into the basin placed beneath the funnel while the suspended matter remains behind on the filter paper. The liquid which passes through the filter is called a *filtrate*.

If two solid substances, say sugar and sand, are mixed together, we can separate them by adding water which is the solvent of sugar, and passing the mixture through a filter. The filtrate will contain sugar which can be recovered by evaporating water.

Distillation—

If we heat or boil a solution, the liquid portion thereof changes into vapour and disappears, while the non-volatile solid portion is left in the form of a residue.

If we desire to get back the liquid that has evaporated all we have to do is to collect that vapour and bring it back to the liquid state by the process of cooling. The liquid thus freed from solid impurities is called a *distillate.* Distillation is the process of converting a liquid into gas by application of heat, and then of restoring it to the liquid state by cooling.

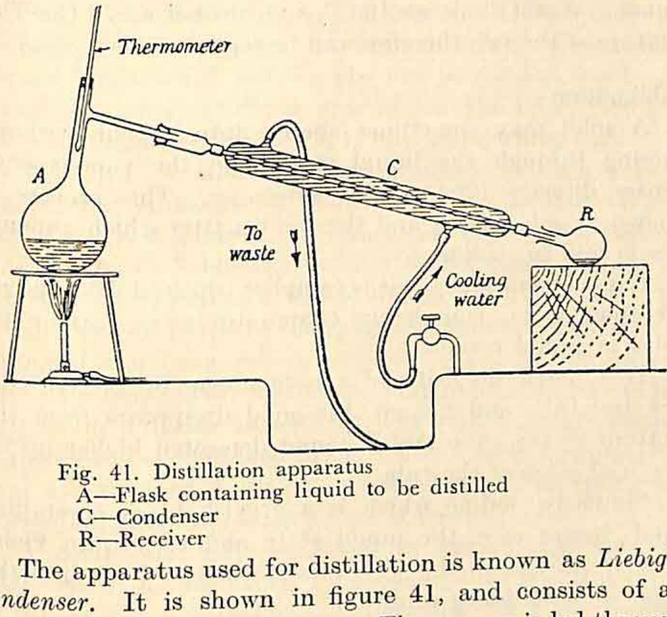

Fig. 41. Distillation apparatus
A—Flask containing liquid to be distilled
C—Condenser
R—Receiver

The apparatus used for distillation is known as *Liebig's condenser.* It is shown in figure 41, and consists of an inner tube and an outer jacket. The vapour is led through the inner tube which is kept cool by passing a stream of cold water through the jacket or the outer tube. The stream of water enters the outer tube at one end and comes out of it by the other end. One end of the inner tube is connected with a flask into which the liquid to be distilled is placed, and the other end passes into a flask called the receiver in which the distillate collects. When the flask

containing the fluid to be distilled is heated, the fluid boils and changes into vapour. This vapour is condensed into a liquid which passes down through the inner tube into the receiver. The solid matter remains in the first flask.

By distillation we can not only purify a liquid and make it free from solid particles, but can also separate two liquids which are mixed together and which have different boiling points. Water boils at 100°C and alcohol at 78°C. The mixture of the two therefore can be separated.

Sublimation—

A solid may sometimes change into vapour without passing through the liquid state, and the vapour condenses directly into a solid substance. This process is known as *sublimation* and the solid matter which vapourizes is said to *sublime*.

A good example of this is camphor which, if left exposed for some time, completely evaporates away leaving no solid or liquid residue.

If a small quantity of sal-ammoniac be placed in a dry test-tube and heated, the solid disappears from the bottom of the tube and is found deposited higher up on the cool sides of the tube.

Similarly, iodine which is a greyish black crystalline solid, jumps over the liquid state and turns into violet vapour when heated. The vapour changes back into the solid state on being cooled.

When, therefore, a volatile solid like any one of the above substances, gets mixed up with sand or non-volatile solid, the two can be separated by the process of sublimation.

Questions

1. Explain the following terms : distillation, sublimation, crystallization.
2. How would you separate sugar from a sugar solution?

CHAPTER II

ELEMENTS AND COMPOUNDS

We are familiar with iron, aluminium, copper, mercury, lead, silver and gold. They are known as metals.

Carbon, sulphur and phosphorus are *non-metals*; oxygen, hydrogen, nitrogen are *gases*. In Chemistry all these are called *elements*. An element means a simple substance, out of which nothing else can be got but itself. A piece of iron may be cut or ground into the finest powder, yet each lump or particle of it is iron and nothing else.

When two or more elements combine to form a substance, that substance is known as a compound. When iron is exposed to moist air it becomes rusty. The rusting is due to the combination of iron with oxygen present in the air, thus forming a compound called *iron oxide*. In colour, weight and behaviour, the compound iron oxide is quite different from iron and oxygen. A compound therefore is made up of two or more elements, united in a definite proportion, to form an entirely new substance unlike any of the elements contained in it. The union of elements to form a compound is always attended with absorption or production of heat or other forms of energy.

A compound may be found in nature, or, can be produced in a laboratory. An element exists in nature or can be had by breaking a compound. But no chemist can create an element.

Table salt, alam, saltpetre, nitre, washing soda, chalk, marble and water are examples of *chemical compounds*.

Chemical compounds should be distinguished from mechanical or physical mixtures. If two or more elements or compounds are merely mixed together, and if each of them retains its individual property or entity, the mixture

is called a *mechanical mixture.* Such a mixture may be made in any proportion.

A mixture, for instance, of sand and iron filings is made without absorption of production of heat energy, and the mixed substances are separable by mechanical means. Further, in the mixture sand behaves as sand, and iron as iron. Each retains its own physical properties.

Air is another example of a mechanical mixture. It is mainly composed of oxygen and nitrogen, with a trace of carbon dioxide and other substances. In air oxygen is not in chemical combination with nitrogen, but if an electric spark is passed through it, a compound known as *laughing gas* will be produced.

If iron filings and sulphur be mixed, the mixture will be a mechanical one. But if the mixture is heated, the two elements combine chemically, and a new compound *iron sulphide* is formed. This substance is quite different from both iron and sulphur, or from their mechanical mixture.

Molecules and atoms—

A *molecule* is the minutest portion into which a substance can be divided without losing its chemical identity. It is the smallest particle of which we can imagine a separate existence. It is conceived that a molecule is made up of still more minute particles called *atoms*. Atoms have no free existence. They are the minutest particles in which elements combine with themselves or with each other. This assumption of the state of matter, helps greatly in understanding Chemistry. It is known as the *Atomic theory*.

According to this theory iron is taken to be composed of a number of iron molecules, and each iron molecule consists of a certain number of iron atoms. Similarly, a molecule of hydrogen consists of two hydrogen atoms joined together. A molecule of oxygen is formed by the union of two

atoms of oxygen. If, however, three atoms of oxygen unite to form a molecule, what we get is no longer a molecule of oxygen, but that of a different substance called *ozone*. This substance is found in sea-breeze and in the atmosphere during a thunder-storm. It is more powerful oxidizer than oxygen gas, and has a slightly fishy smell while oxygen has no odour at all. Thus we see that a slight change in the arrangement and number of atoms, even of the same element, gives rise to the formation of a different substance.

While the molecule of an element is composed of atoms of the same element, that of a compound is made up of atoms of two or more different elements joined together. A molecule of water is composed of two atoms of hydrogen and a single atom of oxygen united together. If in the union the proportion of oxygen atoms is increased, a different substance, called *hydrogen peroxide*, is formed. Hydrogen peroxide has properties quite different from those of water, and is used for bleaching delicate objects like wool or silk, and for washing wounds.

Carbon dioxide gas which is present in the atmosphere, contains two atoms of oxygen and a single atom of carbon, while *carbon monoxide*, a poisonous gas obtained by the burning of coal or charcoal in an insufficient supply of air consists of a single atom of carbon combined with a single atom of oxygen.

A molecule of washing soda or *sodium carbonate* has atoms of three elements joined together namely, two atoms of sodium, one of carbon, and three of oxygen.

Symbols and Formulae—

Just as we write our initials with the first letter of our name, the elements and compounds in Chemistry are designated by their initial letters or symbols.

Thus for oxygen we write O, for hydrogen H, and

nitrogen N. In cases where two different elements have names which begin with the same letter of the alphabet, the two leading letters are chosen to represent them. Chlorine and calcium begin with the letter C, so the first is represented by the symbol Cl and second by Ca. Carbon is indicated by the single letter C.

Many elements are known in Chemistry by their Latin or Greek names, and their symbols, therefore, are taken from Latin or Greek words. Iron is called *Ferrum*; Gold, *Aurum*; Copper, *Cuprum*; Lead, *Plumbum*; Mercury, *Hydrargyrum*. Hence *Fe* stands for iron, *Au* for gold, *Cu* for copper, *Pb* for lead and *Hg* for mercury.

Compound substances are represented by writing together the symbols of elements that form the compound. But this is not all. The symbol of a compound shows how many atoms of each component element has gone to form a molecule of that compound. Water is H_2O while Hydrogen peroxide is H_2O_2. This means that a molecule of water is made up to two atoms of hydrogen and one of oxygen, while in a peroxide molecule two atoms of hydrogen have combined with two atoms of oxygen.

The formula of water thus indicates that one volume of oxygen has combined with two volumes of hydrogen to form water. But there is still something more shown by the formula. We know that oxygen is sixteen times heavier than hydrogen and can, therefore, say from the formula that the proportion by weight of hydrogen and oxygen in water is 2 : 16, or 1 : 8.

Chemistry has further assumed that the atoms of some elements like hydrogen and chlorine have one hand or bond, while some like oxygen has two hands. Carbon has as many as four hands. In a molecule of water a two-handed oxygen atom holds a single handed hydrogen atom by each hand. Pictorially this is shown as H—O—H.

Chlorine having only one hand, when it combines with hydrogen, each stretches forth its one arm to unite, and the two joined form a molecule of hydrochloric acid (HCl).

The four-handed carbon atom grasps each oxygen atom by two hands to form carbon dioxide ($O=C=O$).

Acids, Alkalies and Salts—

There are three important classes of chemical compounds which deserve special mention.

Salts usually are neutral in reaction, and generally have no action on the litmus paper. The common table salt ($NaCl$) is a salt but all chemical salts need not be salty in taste. Chalk is an example of this.

Acids are sour in taste and turn blue litmus paper red. Litmus is a dye with which small strips of paper are coloured for chemical test.

Alkalies are soapy in touch and turn red litmus paper blue.

The alkalies best known to all, are lime-water $Ca(OH)_2$, caustic soda ($NaOH$), caustic potash (KOH). They are respectively the oxides of calcium, sodium and potassium dissolved in water. If an alkali is treated with an acid in the right proportion, they neutralize each other, and form a salt. If caustic soda ($NaOH$) is treated with sulphuric acid (H_2SO_4) it forms the salt known as sodium sulphate (Na_2SO_4), or *Glauber's salt*. Caustic potash treated with acids, gives us various potassium salts. For example, it forms with hydrochloric acid potassium chloride, with sulphuric acid potassium sulphate, and with nitric acid potassium nitrate, or saltpetre.

By neutralizing lime-water or calcium hydroxide with carbonic acid (H_2CO_3) we get the salt called the carbonate of calcium, or common chalk.

We can produce salts even without neutralizing alkalies. For instance, by dissolving copper filings or copper oxide in sulphuric acid, we get the well-known blue vitriol or copper sulphate. Granulated zinc put into sulphuric acid, gives us zinc sulphate. Zinc takes the place of hydrogen in the acid and liberates that gas which bubbles out of the liquid.

The alkalies and the oxides mentioned above are also called *bases*, as they contain the requisites for yielding a salt.

Acids form salt when acting on the bases, because hydrogen atoms in them get replaced by the atoms of the metals in the bases.

A sulphuric acid salt is called a sulphate ; a nitric acid one a nitrate, a carbonic acid one a carbonate and so on. But the salts of hydrochloric acid are called chlorides as they contain merely the metallic and the chlorine atoms.

Acids as well as alkalies should be handled with care. Undiluted they are apt to give you burns. Special care should be taken of strong acids like the sulphuric and the nitric. For diluting acids the proper way is to add the acid drop by drop to water. Never pour water into the acid. It is dangerous.

Questions

1. Mention a few elements and compounds you are familiar with.
2. Distinguish between a compound and a mechanical mixture.
3. Describe the properties of an acid and an alkali.
4. Explain the following :—(*i*) Atoms, (*ii*) molecules, (*iii*) salts.

CHAPTER III

AIR

Composition of air—

The earth is covered by an envelope of air. Air extends more than fifty miles above us, and we are living on an ocean of air. The wonder is that we are continually breathing air, yet we can neither see nor taste it. We are moving through air without experiencing any difficulty. But we feel the want of air for breathing if we go down under water ; and then we feel suffocated.

A mouse dies if kept in a closed vessel from which air has been drawn out. The same thing will happen if an animal be kept for a sufficient time under a bell-jar without any opening. A burning candle goes out after a time if placed within an air-tight vessel. Fresh air supports respiration and keeps the fire burning. It is indispensable for breathing or for the purpose of burning things. It is also soluble in water ; aquatic animals such as prawns and fishes, breathe the dissolved air.

Air is invisible because it is a mixture of colourless gases which have no odour or smell. Besides, air contains a fair amount of moisture or water vapour, which varies with the season and the temperature of air. The water vapour in air condenses into water when it comes in contact with a cold surface, or when it is cooled. While holding a glass of ice-cold water, you must have noticed that drops of water collect on the outside of the glass even when it is wiped dry. These drops comes from the air which held water in the form of vapour. For the same reason dew is deposited.

Smokes or fumes from mills contaminate air, and make the difference in the composition of air of an

industrial town, and that of a village. Dust particles hang in the air and are best seen when a beam of light passes through a dark room. These should be considered to be the impurities of air.

Air is mainly composed of nitrogen, oxygen and carbon dioxide gases. There are traces of other gases also. Nearly four-fifths of air is nitrogen, and one-fifth oxygen. In other words, 80 volumes of nitrogen are mixed with 20 volumes of oxygen to form air ; this mixture contains ·04 per cent of carbon dioxide as well. If we go by weight, 77 parts of nitrogen and 23 parts of oxygen are present in air.

Since air is a mechanical mixture, and not a chemical compound, each constituent part retains its characteristic property, and air should have the aggregate properties of all the gases of substances present in it. Now nitrogen is an inert gas. It does not enter into combination with other substances and has no effect on other things. It forms the bulk in air and dilutes the oxygen gas which is the active agent in air. It is the oxygen gas in air that keeps men and animals alive and supports combustion.

Without oxygen we could have no fires, and no life would be possible. One can go without food or drink for some time, but not so without air or rather the oxygen contained in air.

Chemical properties of air—

Oxygen in air causes rusting of iron by joining with the latter to form iron oxide, or rust. When coal, or charcoal, which contains carbon, burns in air, the oxygen of air joins with the carbon of coal to form carbon dioxide. Thus the air becomes poor in oxygen and rich in carbon dioxide. Similarly, when sulphur, or magnesium, or any other

substance, burns in air, oxygen unites with that substance to form a new compound and therefore, the volume of oxygen that has gone into the combination, is lost from the air and the air thereby becomes deficient in oxygen. If all the oxygen is thus used up in the burning of a substance, the air being devoid of oxygen, will fail to support combustion, and the fire will go out. Nothing would burn up in such spent-up-air.

Again, in course of breathing, we take in oxygen from air and give out carbon dioxide which passes back into air. The used or exhaled air, therefore, is poor in oxygen and rich in carbon dioxide. As millions of people for thousands of years are absorbing oxygen from air, and giving out carbon dioxide, we may be wondering why all the oxygen in the air has not been used up and the air around us is not full of carbon dioxide. Such a thing would have happened, if the green plants did not absorb the carbon dioxide from air and returned oxygen.

Carbon dioxide, taken from air by the green leaves of plants, is broken in those leaves with the help of the sun's rays into carbon and oxygen. The carbon goes to form the food of plants, and oxygen is liberated. Thus green plants maintain in nature the balance between oxygen and carbon dioxide present in air.

Since air is a physical mixture, the composition of air is determined by separating the constituent substances from a measured quantity of air, and finding out the amount of each that was present in the known volume of air. Now water vapour is absorbed by calcium chloride or by sulphuric acid, carbon dioxide by lime-water, by caustic soda, or by baryta water. Therefore, if air is passed through the respective tubes containing these substances, it is freed from water vapour and carbon dioxide. Then oxygen is extracted from the residual air by burning

copper in it. Copper will unite with oxygen and will gain in weight, forming copper oxide. From this we can calculate the amount of oxygen that was present in the measured volume of air. The remaining substance will be nitrogen gas and by measuring it we come to know the proportions of different substances that were mixed to form air. We can draw air through a tube containing a chemical for analysis, by connecting one end of the tube with an aspirator, or suction pump, and keeping the other end open or connected with a flask containing air.

If we analyse samples of air from different localities we find that the proportion of the above constituents is not the same in all cases. This is so because air is a mixture of several gases, and not a chemical compound of these.

Air can also be liquefied by applying high pressure and lowering the temperature. Liquid air is highly explosive.

Questions

1. State the chemical composition of air.
2. Why do things burn in air ?
3. Describe the chemical properties of air.

CHAPTER IV

SOME EXPERIMENTS

Experiment to find the effect of a closed volume of air on the rusting of iron—

Take a glass tube with one end open and the other end sealed. Moisten it with water. Put some iron fillings in the tube and shake. The iron filings will stick to the inner surface of the moist tube. Invert the tube and put its open

end under water in a basin or jar (Fig. 42). Note the condition of iron filings and the level of water in the tube at the beginning and end of the experiment.

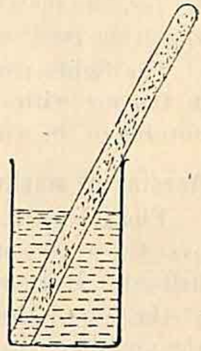

Fig. 42. Rusting of iron

After a week or so, the iron filings would be found rusted, and the level of the water within the tube would rise higher.

Now oxygen present in the air passes into combination with iron, forming iron oxide or rust ; the air enclosed within the tube, therefore, due to this loss of oxygen, diminishes in volume, causing a partial vacuum in the tube. Water rises up in the tube. The remaining portion of the tube contains air minus its oxygen. The difference in the level of the column of water in the tube at the beginning and end of the experiment, shows the amount of oxygen lost in the rusting of iron. The experiment also proves the existence of oxygen in an uncombined state in air, for no other substance causes rusting of iron.

Burning of a candle in a closed volume of air over water—

Take a trough, put some water in it. Fix a candle on a porcelain basin. Float the basin on the water in the trough, and light the candle. Take a bell-jar with an opening at its top, which can be closed air-tight by a stopper. Put the jar over the burning candle and close the top-opening of the jar (Fig. 43). After a time the candle goes out. Now open the stopper and plunge a lighted match into

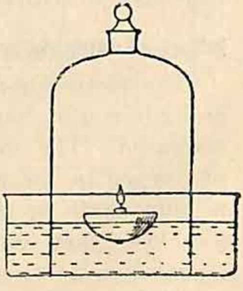

Fig. 43. Burning of a candle in a closed volume of air

the jar, the match goes out. Note the level of the water within the jar as well as in the trough.

The light is extinguished because the oxygen present in the air within the bell-jar has been used up by the burning of the candle.

Burning of sulphur or phosphorus—

Float a piece of sulphur, or phosphorus, in a crucible over the water contained in the trough. Cover it with the bell-jar. Introduce lighted taper through the opening at the top of the bell-jar and set fire to the substance in the crucible. Remove the taper and close the opening of the jar. Note the level of the water inside and outside the jar after the flame has disappeared ; and test the enclosed air by inserting a lighted taper into the bell-jar through the top opening. The light will go out.

It is seen that as a result of burning of sulphur or phosphorus in the enclosed air, the air not only becomes incapable of supporting combustion or burning, but diminishes in volume as shown by the rise of water level within the jar. Any rise or fall in the level of the water within the jar, is detected by comparing the level of the water inside the jar with that in the trough outside the jar.

Effect of burning magnesium in air—

If a piece of magnesium in a crucible is weighed before, and after it is burnt in air, we find that its weight has increased. The increase in weight is due to the union of oxygen in the air with the magnesium, forming magnesium oxide or the ash of magnesium. The air, therefore loses that amount of oxygen which unites with the magnesium to form magnesium oxide.

The volume of oxygen used up by the burning of magnesium can be determined by following the same method as before.

Questions

1. Describe the process of rusting of iron.
2. Make an experiment to show that oxygen is the active agent in air.

CHAPTER V

OXYGEN

Oxygen is plentifully distributed in nature. It occurs in combination with other substances such as water or metallic ores or salts.

Preparation of oxygen—

If red oxide of mercury, or oxide of lead is heated, oxygen is given off. It can be prepared in a laboratory

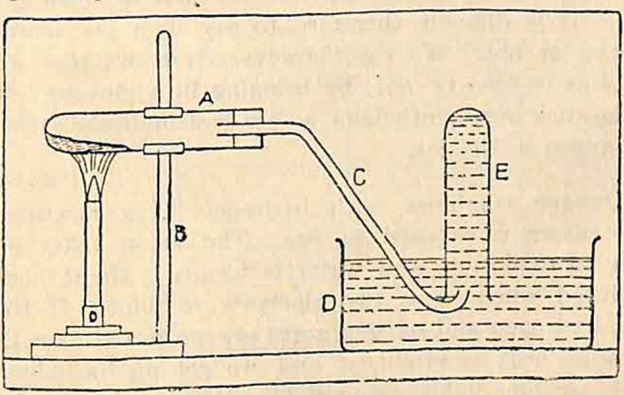

Fig. 44. Preparation of oxygen
A—Hard glass tube containing the mixture to be heated for yielding oxygen
B—Retort stand
C—Delivery tube
D—Bowl of water
E—Tube filled with water at the start for collecting oxygen by replacing the water
O—Bunsen burner

by heating potassium chlorate and manganese dioxide in a test-tube. The tube is fitted with a delivery tube. The oxygen gas is collected by inverting a glass jar filled with water over the beehive-shelf, and introducing the free end of the delivery tube under the shelf. The gas will fill the jar by displacing the water (Fig. 44).

Properties of oxygen—

Oxygen is heavier than air. Therefore it can be poured like water from one jar to another. It can be kept in jars with its mouth up. If a glowing splinter of wood is introduced into a jar of oxygen, the wood bursts into flame but the gas itself does not catch fire. We say, therefore, that oxygen supports combustion, but is not inflammable.

Oxygen is colourless and has no taste or smell of its own. It is difficult therefore to say if a jar contains oxygen or not. We can, however, test whether a jar contains oxygen or not, by bringing in a glowing stick. If the stick bursts into flame we are certain of the presence of oxygen in the jar.

Oxygen combines with hydrogen, if a mixture of these gases is exposed to fire. The union takes place with an explosion, and water is formed. Great heat is produced when these two elements combine. If therefore, hydrogen and oxygen gases are projected over lime, a white heat is produced and we get an incandescent light, or lime-light. Lime-light has now been replaced by several kinds of electric lamps. Great heat is produced when a mixture of acetylene and oxygen burns and this is used for welding iron.

Coal burns in oxygen forming carbon dioxide and the solid residue left is ash.

Red-hot iron burns in oxygen with brilliant scintillations; most metals in burning combine with oxygen forming oxides.

It is due to the presence of oxygen in air that we can light a fire or make things burn.

Oxygen is an absolute necessity for the maintenance of life. Both plants and animals require it for breathing. But as it is an active substance it should be diluted before use. In air we find the oxygen gas in the dilute form.

Oxygen is soluble in water. Aquatic animals, such as fishes, require oxygen like the terrestrial animals. They get it from air dissolved in water. If oxygen was not soluble in water, life under water would have been impossible.

We cannot get oxygen for breathing from water when we are swimming or diving under water. We are dependent for our supply of oxygen on atmospheric air.

Oxygen has many commercial uses and it is kept in store in iron cylinders.

CHAPTER VI

SOME OTHER GASES

Hydrogen and its preparation—

Hydrogen is a gas and it rarely occurs in nature in a free state. It is a constituent of water, and therefore, when water is decomposed by a current of electricity hydrogen and oxygen gases are liberated. It is produced

in a laboratory by treating commercial zinc with sulphuric acid (Fig. 45).

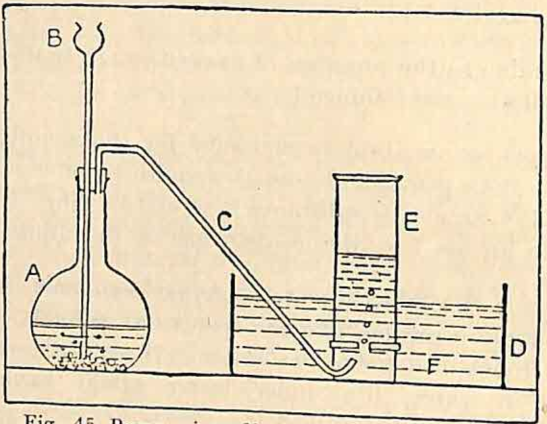

Fig. 45. Preparation of hydrogen
A—Flask containing zinc and closed with a stopper bored with two holes
B—Thistle funnel for pouring in acid
C—Delivery tube
D—Bowl of water
E—Gas jar filled at start with water for collecting hydrogen gas generated in the flask
F—Beehive-shelf

Properties of hydrogen—

Hydrogen is the lightest gas known. Owing to its lightness, it rises higher up in air, and that is why balloons are filled with this gas. For the same reason jars filled with hydrogen gas are kept with their mouth inverted. In pouring hydrogen gas from one jar to another we hold down the mouth of the jar in which the gas is to be collected, at an angle to the other jar which is also held inclined. The gas from the lower jar escapes into the upper.

Hydrogen is colourless and tasteless like oxygen. It has no odour. It is inflammable, but does not support combustion. It can, therefore, be distinguished from oxygen.

If a lighted taper is introduced in a jar of hydrogen, the gas burns but the light of the taper is extinguished.

When hydrogen burns in air it unites with oxygen forming water, but nitrogen is left behind. If hydrogen and oxygen gases are mixed in a bottle they will not form water or a compound. But as soon as the mouth of the bottle is held over a flame, the two gases combine to form drops of water.

Properties of nitrogen—

Nitrogen is the most plentiful gas in the world, forming nearly four-fifths of the atmosphere. The properties of nitrogen are negative. It is tasteless and colourless. It is neither inflammable nor will support combustion, and, thus, differs from hydrogen or oxygen. We say, therefore, that this gas is inert, or chemically inactive; it will not readily enter into combination with other substances under ordinary conditions.

As it is present in air, animals and plants inhale it along with other gases but they can make no use of it and so breathe it out.

It is, however, not altogether a useless gas in as much as by diluting oxygen in air, it prevents too rapid burning of things, or combustion of tissues, which oxygen would have done if left alone.

Nitrogen forms important compounds with other substances. The nitrogenous food which animals need for building up their body, is made by plants from nitrogen. The Bengal saltpetre, or nitre, is used as a manure, and is an essential thing for the preparation of gunpowder.

Carbon dioxide—

Carbon dioxide gas is a chemical compound, and not an element like oxygen, hydrogen or nitrogen. It is formed

when substances like coal, wood and paper, which contain carbon, burn in air. The carbon of coal unites with oxygen in air, yielding carbon dioxide gas. It can be made in the laboratory by treating chalk with hydrochloric acid.

It is given out when animals breathe. It is present in a small quantity in air. It is of utmost importance to the vegetable kingdom. Plants get their supply of carbon from carbon dioxide present in air. Green leaves of plants seize carbon dioxide from air and convert it with the help of sunlight into starch or vegetable food. To animals, it is not a poisonous thing, but yet if inhaled in a large quantity it is harmful, the reason being that it cannot support respiration.

The smoke, which comes out when coal or wood burns, contains various other gases besides carbon dioxide and often has a pungent smell. The smell is not due to carbon dioxide, which has no odour, but to some other substances. Again, a few of them, like the carbon monoxide gas, are poisonous, and hence it is risky to sleep in a room with coal or charcoal burning and doors and windows closed.

Carbon dioxide gas is soluble in water, forming carbonic acid. Aerated water, which is wrongly called soda water, is a solution of carbon dioxide in water made under high pressure. The gas bubbles out when the bottle is opened.

Carbon dioxide gas is heavier than air. If you turn a jar filled with this gas upside down, the gas falls out, and the jar becomes filled with air. Since it is heavy, it will hang like a smoke screen over a flame or fire if poured over it, and thus will cut off the supply of air which the fire needs to burn. The fire goes out for want of oxygen. Carbon dioxide is, therefore, used in fire extinguishers

It is a colourless gas and is invisible like oxygen, hydrogen and nitrogen. But it can be distinguished from oxygen, as the latter supports combustion while

carbon dioxide does not. If a glowing match stick or a burning taper be introduced into a jar of carbon dioxide, the fire goes out. Again, it is non-inflammable and it will not catch fire, or burn like hydrogen. It may be remembered that nitrogen has a similar property. It can, however, be distinguished from the latter as well as from other gases. It has a property which is not shared by any other substance. It turns lime-water milky. If you breathe on lime-water the latter turns milky or turbid for the same reason. Now lime-water is known as calcium hydroxide and is made by dissolving lime in water. Calcium hydroxide turns into calcium carbonate, that is, lime-stone or chalk by the action of carbon dioxide, or rather by carbonic acid. Chalk is insoluble in water, therefore, with its formation, the lime-water turns turbid. The lime-water test is of great advantage in detecting carbon dioxide.

Builders' mortar is composed of lime and sand, or "shoorkee", made into a paste with water. The setting of mortar is due to the conversion of lime into hard lime-stone or calcium carbonate by absorption of carbon dioxide from the air.

Questions

1. Compare the properties of oxygen and hydrogen gases.
2. What test would you make for detection of carbon dioxide in air ?
3. What are the commercial uses of oxygen and carbon dioxide ?
4. How would you distinguish nitrogen from hydrogen ?

Secondly, the combination of these two gases takes place in a definite proportion. Two volumes of hydrogen gas always combine with one volume of oxygen, to form two volumes of water or steam. If any one of the combining gases is in excess of the required proportion, it will be left behind after the explosion.

If a soda-water bottle be filled with hydrogen and oxygen gases, and the mouth of the bottle be held near a flame, the two gases combine with an explosion, and drops of water are found within the bottle. We do not exactly know from this experiment the volume of water produced. Comparison by volume is possible only when the substances are all in a gaseous, or in the same state. Now water changes to steam, or gaseous state, when its temperature is 100°C. If, therefore, the experiment is carried in a temperature over 100°C, both the combining gases and their product would be at the same temperature and on the same state, and a comparison of their respective volumes would be possible.

Hard and soft water—

Water occupies more than two-thirds of the entire surface of the earth. There is a continuous evaporation of water from the surface of the earth. The water vapour condenses and the water is precipitated as rain. The rain water swells rivers or is collected in ponds. Some of the water, however, percolates into the soil and is stored within impervious beds of rocks below the surface of the earth. The subterranean water comes out when an outlet is found as the spring water.

Water has great solvent power. Therefore, in passing through rocks it dissolves many minerals contained in the rocks. Numerous salts are thus found dissolved in it. Sea water is salty having a large amount of sodium and magnesium chloride dissolved in it.

Rain water comes very near to pure water, but it holds

other substances in solution particularly the gases present in atmospheric air. Distilled water is the purer form of water which is readily available to us.

The taste and property of water vary according to the nature of the substances it contains, and depend greatly on the sources from which it has been obtained.

Water which freely forms lather with soap is called *soft water*. But water from certain wells, springs or rivers does not lather freely with soap, and, therefore, for washing purposes a large quantity of soap has to be used before soapiness or lather could be had. Such water is called *hard water*.

The hardness of water is due to the presence of calcium and magnesium salts in it. If carbonates of lime and magnesium be found dissolved in water, the water is said to be temporarily hard. It is called temporary hardness because it can be removed by boiling. Permanent hardness of water is due to the presence of sulphates or chlorides of calcium and magnesium, and these salts cannot be removed from water by boiling. Both temporary and permanent hardness can be removed by adding potassium and sodium carbonates to water, because these latter salts will precipitate calcium and magnesium salts, while they themselves pass into solution in water and are helpful for washing purposes.

We know that water is converted into steam, and this conversion is effected in steel boilers. If the water is hard and if the boiler be filled with such water, the salts of lime will be precipitated or deposited in the boiler, and as a result, the inner wall of the boiler will be corroded. It is necessary, therefore, to avoid hard water for use in the boiler.

Questions

1. Mention the chief sources of water in nature.
2. What do you understand by hard and soft water ?
3. State the chemical composition of water.

PART III

BIOLOGY

CHAPTER I

CHARACTERISTICS OF THE LIVING

Biology is the science of life. It deals with all aspects of living organisms. Plants and animals are living organisms. They take in food, breathe, grow and reproduce, and so are readily distinguishable from non-living objects such as earth, stone and river.

Living organisms exhibit movements. But motion is not peculiar to living organisms alone. Light travelling at a tremendous velocity, swift-flowing waters, or, a moving locomotive engine, are not called living things.

A living organism moves in search of food, or seeks shelter to avoid danger to its life. Its movements, however, are not beyond the influence of the physical forces such as light and gravitation, which operate on inanimate objects. Insects, for example, are attracted by light. Roots bend towards the earth, and the shoots curve towards light. The sun-flower follows the direction of the sun. The sensitive *Mimosa* plant responds to touch, or to an external stimulus, by folding its leaves.

Again there are countless forms of plants and animals that remain fixed at one place without any power of locomotion. While plants are well-known for remaining rooted at one place, the sponges and corals furnish the familiar examples of fixed life in animals.

Activities of life—

A living organism shows various activities. It secures

its own food and thus differs from a locomotive engine which must be supplied with fuel before it can work.

The food taken in is changed within its body into such products as starch, sugar, fat, etc., that nourish the body. These are finally rendered into the living substance comprising the body. The process is called *nutrition*.

Plants and animals take in oxygen from air. Oxygen burns the living tissues inside the body so as to evolve energy. Carbon dioxide is a product of combustion and is let out of the body. This gaseous exchange goes on by night and by day and is called *breathing* or *respiration*. It is a characteristic activity of a living organism and is not shown by any non-living object.

In consequence of combustion and other changes inside the body, the tissues are broken down and waste products are formed. The waste products are injurious and are eliminated from the body. This process is called *excretion*. Urine is an excretory product.

Excretion should be distinguished from *secretion*. Milk is a secretory product.

In the body both constructive and destructive changes are going on. Nutrition not only helps in the repair of the loss made by the destructive processes but also leads to the growth or increase in bulk of the body. The growth in a living object is different from the increase in volume or weight of a non-living thing. A crystal of sugar for instance grows by the addition of sugar. A living organism grows at the expense of the food which is quite different in composition from the living substance comprising its body. The growth is also accompanied by a differentiation of the body starting from birth to old age. Growth cannot go beyond a certain limit in the living organism. The full size is reached when the organism attains maturity.

The mature organism reproduces, or leaves progeny.

The reproduction is a remarkable characteristic of the living, and cannot be found outside the living world. The propagation of the race is done in two ways (*a*) *asexual* and (*b*) *sexual*. A plant can be propagated by cuttings, and the simplest forms of animal types multiply by splitting their body into two halves each of which grown into an individual. In certain cases, a portion of the body bulges out and becomes separated from the parent body. This is known as *budding*. These are the instances of asexual mode of reproduction. In sexual methods of reproduction certain cells, called the reproductive cells, are produced. These give rise to the formation of seeds in plants, and eggs in animals. The seed develops into a seedling, and the egg into a baby. Since living organism display the activities enumerated above, namely, response to external stimuli, locomotion, nutrition, respiration, excretion, growth and reproduction—these activities are considered to be the characteristics of life.

Protoplasm—

The seat of all these operations, however, is the living substance called the *protoplasm*. It looks more or less like a thin jelly, or a soapy solution, and contains carbon, hydrogen, nitrogen, phosphorus and other chemical elements. But if these be compounded together in any proportion, they cannot form protoplasm. It is a substance peculiar to the living organism and is nowhere found in the inanimate world.

Cells and tissues—

The protoplasm is differentiated into a shining speck called the *nucleus* and the remaining mass is called the *cytoplasm*. A tiny mass of protoplasm with a nucleus is called a *cell*. Each cell absorbs food, respires, grows and divides. The nucleus is the important element in the cell because it controls the activities of the entire cell. If it is taken out of

the cell, the latter cannot divide or multiply. Certain plants or animals have their body composed of a single cell (Fig. 50). While in the majority the body is composed of a number of cells. Each cell is capable of dividing into two halves each of which grows into a cell. Cells assume various forms and group themselves to form *tissues* for carrying on a particular type of work. Various kinds of tissues are present in the body. Wood is a kind of tissue in plants. Muscles and nerves are examples of living tissues in animals.

Different tissues combine to form an organ. An organ may be concerned with intake of food, or circulating a nutritive fluid to different parts of the body, or with breathing. An organ may be set apart in the body for eliminating waste products or for the purpose of reproduction. It is a question of division of labour and specialization. According to the nature of work an organ performs, it is called digestive, respiratory or excretory organ. Our lung is a respiratory organ. Foot is a locomotory organ. Different organisms have different types of organs. The respiratory organ of a plant is different from that of an animal. The digestive organs of a cow are not of the same type as those of a worm or of a man. In certain living organisms a few of the organs may be lacking, and in such cases their work is taken up by other parts of the body. A plant has no eyes still it reacts to light. An earthworm has no hand or foot, or eyes, or ears, yet it is doing what a highly organized body does in maintaining life, namely, procuring food, respiring and reproducing.

A *bacterium* is also a living organism but its body, unlike that of an animal, is composed of a speck of protoplasm devoid of a nucleus. Bacteria multiply very rapidly and some of them cause disease in man and animals.

Living organisms do not originate from mud or slime. Life comes from life.

The body of living organism is either radially or bilaterally symmetrical. In radial symmetry, a body is divisible into two equal halves by as many planes as there are radii. A sphere, the stem of a plant, and the jelly fish, possess a radial symmetry. In bilateral symmetry, a body can be divided by one and only one plane into two exact halves. A leaf has usually bilateral symmetry. Fish, frog, man too, have bilateral symmetry.

Adaptation—

Plants and animals are widely distributed over the surface of the earth. Some inhabit the vast hot sandy deserts, others live in the plains, a few make their abode on the top of the snow-clad mountains. A vast assemblage of forms passes their life under water. They may occur in fresh-water pools or rivers, or float on the surface of the sea. A few are found at great depths of the sea where sunlight does not penetrate, and darkness prevails.

Each has to solve its own problem of food, and the manner in which it can best save its own life and that of the children against the rigours of a climate or from destruction by other animals evokes our admiration.

While the majority of the living organisms are free-living, securing their own food and leading an independent life, a few make their home on the body of another plant or animal, and become dependent on them for the supply of nourishment. They are called *parasites*, and the organisms which harbour them are known as *hosts*. From honourable guests the parasites may turn into hidden enemies, menacing the life of the host.

Plants and animals show wonderful plasticity to these different conditions of life. This is called *adaptation*. Their habits and structures are in harmony with the environment or the surroundings.

The stick-insects dwelling on trees look like dry twigs and thereby escape from death by birds which prey on them. The 'Kalima' butterfly found in Assam, closely resembles the leaves of plants. The polar bear harmonizes in colour with its surrounding ice.

Animals living in dark caves have no necessity of a visual organ, and are blind.

Tadpoles and fishes living in torrential hill streams, have suckers or cups on the ventral surface of the body, by means of which they stick to submerged rocks and are thus prevented from being carried away by a rapid current of water. While their close relatives living in still water have not to contend against stream and have no suckers on their body.

Tapeworm living within the gut of an animal is a parasite ; it develops hooks and suckers for fixing on the host and has no alimentary canal to take in food. It absorbs food through its skin. The 'Cuscuta' or dodder is a parasitic plant ; it has no leaf, it draws nourishment from its host.

The desert plants in order to preserve moisture in their body, have thick and fleshy stems and their leaves are reduced and changed to thorns and spines. Plants living in moist places have large leaves with expanded surface to facilitate quick evaporation of water from them.

Questions

1. State the distinctions between the living and non-living.
2. Give an account of the various activities of a living organism.
3. Explain adaptation by citing concrete examples from the plant and animal life.

CHAPTER II

Distinction between plants and animals and their dependence on each other

Plants like animals cannot walk about in search of food. They remain fixed at a place sending out roots in the soil for absorption of mineral matters dissolved in water. They spread their leaves to catch the sun's rays and take carbon dioxide from air. Soil and air are the two sources of food of the plants.

Animals do not thrive upon such materials as are present in the soil or in air. They take in substances which are manufactured by plants from air and the soil, and thus are dependent for their food supply on plants or on other animals that draw their sustenance from plants.

Plants absorb solar energy by means of green pigments called *chlorophyll* present in their leaves. The chlorophyll is non-existent in the body of animals, and the latter cannot utilize the sun's rays in the same way as the plants do.

The primary distinction between the two forms of life lies, therefore, in their mode of nutrition. But there are exceptions. Insectivorous plants obtain their supply of nitrogen and carbon by entrapping and digesting insects. Moulds or fungi are plants that grow upon decaying vegetable or animal corpses and lack the characteristic green colour of plants having no chlorophyll in their cells.

Plants take in carbon dioxide from air, give off oxygen, while animals take in oxygen from air and give out carbon dioxide.

Plants and animals differ not only in their mode of life but also in their structure.

The cells composing the body of plants have thick cell-walls made of cellulose, a substance allied to wood, while the cells of animals have no such walls.

Tissues formed by division, differentiation, and grouping of cells, are not similar in plant and animal body. Higher animals have muscles, nerves and sensory organs like eyes and ears, while plants have no such structures. In plants the nutritive sap carrying the food matter, passes through woody fibres arranged end to end, and there are no separate blood-vessels like arteries and veins of animals.

The dissimilarity disappears, however, as we go down to simple forms of animal and plant life, and it is not easy to say which one is the plant and which one is the animal.

The very mode of life of plants and animals makes them interdependent on each other.

We get our supply of starch from rice, potato and sago plants. Sugar comes from the sugarcanes; oils from castor, mustard, seeds and cocoanuts; turpentine from the pine tree. Peas and grams are a rich source of nitrogenous or protein food.

Animals live upon plants, and their dead and decaying bodies give back to the soil, the nitrogenous compounds required by the plants as food. The waste products such as urine and excreta eliminated by animals make the soil rich for vegetable life.

Animals take in oxygen and give off carbon dioxide. The carbon dioxide present in air is removed by the plants, and oxygen is returned to air. Insects collect the nectar from flowers, and the flowers in return are pollinated by insects.

Questions

1. State the distinction between animals and plants.
2. Describe the mode of nutrition in a plant and show in which way it differs from that in an animal.
3. Show in which way animals are dependent upon plants.

CHAPTER III

BOTANY

The plant kingdom—

Plants have diverse forms. A few of them reproduce by flowers and bear seeds. They are known as *flowering plants.* Our common garden, or cultivated plants and fruit trees are the flowering plants, and have seeds enclosed within seed-boxes or ovaries. These, however, differ from the coniferous trees such as the pine and cedar, in as much as in the latter, the seeds are not enclosed in ovaries or seed-boxes but are exposed on the flowers.

Ferns and mosses have no flowers and so they are different from the flowering plants. Leaves of ferns are called fronds, and bear spores on their under-surface.

Simple plants called algæ float in water as filaments or spread as a carpet on the bottom of a tank. They have no woody stem or flowers of any kind.

The plants mentioned above have chlorophyll and are green in colour. The moulds and fungi are a group of plants marked off from the above in not having the chlorophyll. Their body is composed of protoplasmic threads and gives off stalks bearing spores. Some of them cause diseases of plants such as rust in the wheat. Toadstool is an example of fungus. Ring-worm is a parasitic fungus.

Lichens form a different group of plants from the above, and are found encrusting the moist trunk of trees or walls.

The principal parts of a flowering plant are roots, stems, leaves, flowers and fruits. The plant is anchored to the soil by the roots. The stems bear leaves, flowers and fruits.

Flowers are the reproductive organs and change to fruits. Fruits contain seeds. Seeds sprout into seedlings.

The flowering plants can be grouped as herbs, shrubs and trees. Herbs have soft stems. Peas, cabbage and onions are known as herbs.

Shrubs have numerous woody stems springing from the ground but none of them reaching great heights. 'Jaba' or the China rose, the croton and the rose-bush come under shrubs.

Trees are giants of the vegetable kingdom. They have a strong and woody stem. Branches spring from the stem. The mango is a familiar tree.

Plants can be grouped according to the duration of life as follows :—

Plants which live for one year or a season, are known as annuals.

Those which live for two years or seasons, are called biennials.

Those which live for successive years are known as perennials.

Herbs can be annual, biennial or perennial. Annual herbs last for a season and wither away.

Peas, beans, rice and jute are annual herbs.

Biennial herbs are concerned in the first year or season, with storage of food, and flowers and seeds are produced in the second year or season. Onion is an example of biennial herbs.

In the perennial herb the nourishment is stored in the underground stem or root, and aerial shoots are given of in successive years.

Canna and plantain are perennials. Shrubs are generally perennials. Trees may be annuals or perennials living over hundreds of year.

Questions

1. Name the parts of a common flowering plant you know.
2. Mention the names of a few plants which are of use to man.

CHAPTER IV

GERMINATION

A seed if sown develops to a young plant. It can remain for a long time without sprouting, and usually starts germinating or developing when soaked in water or planted in the soil. The seed is covered with a coat and contains a scar. The scar marks the portion by which it was attached to the fruit. In the pea the scar looks like a black mark. Close to the scar there is a pit through which the primary root comes out as the germination proceeds. The seed of gram and pea contains inside its seed-coat, a pair of thick fleshy hemispherical lobes which meet at their edges. These are seed-leaves and are called *cotyledons*. If the seed-leaves are separated after soaking in water, a minute elongated body is seen attached to their inner surface. This represents the axis of the embryo or the first baby plant (Fig. 46). The pointed end of the axis grows into a root and is known as the *radicle* or the future root. The opposite end of the axis is the *plumule* or the future shoot. If the seed is sown or soaked in water, the seed-coat splits. The first stage of growth is the lengthening of the axis and developing of the root from the radicle. The root-end grows downwards into the soil and avoids light. If the germinating seed is inverted, the root will bend down so as

to turn always towards the earth. On reaching the soil the root gives out root-hairs and sends out branches. The cotyledons or the seed-leaves are thick and fleshy as they have reserve food stored in them for the nourishment of the growing embryo. By the time the roots reach the soil, the reserve food is depleted and the cotyledons

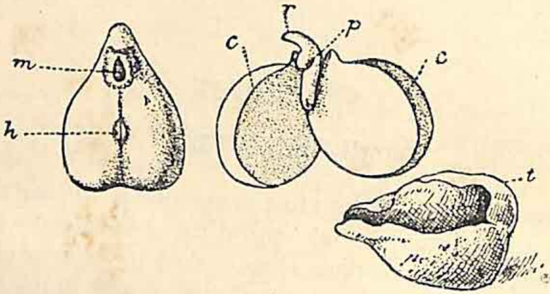

Fig. 46. Gram seed
m. Scar *t*, Seed-coat removed
c, Cotyledons *r*, Radicle *p*, Plumule

shrivel. The plant is now drawing its own food from the soil by its roots and does not stand in need of any reserve food. The stem shoots up in the air and puts forth buds which grow into leaves.

Pea and other plants which have two seed-leaves, came under *dicotyledons*.

Rice, grasses and the cocoanut plants have a single seed-leaf in the embryo, and are grouped under *monocotyledons*.

In rice the reserve food is called the *endosperm*. It is large but is stored not within the seed-leaf but outside it. Its embryo with the single thin seed-leaf, is situated at one end of the seed (Fig. 47). Roots come out in three days. The first or primary root is replaced here by a tuft of fibrous roots (Fig. 48). The stem bears long leaves. The seedlings of some cultivated variety of rice are transplanted.

These plants require abundant water supply for their growth.

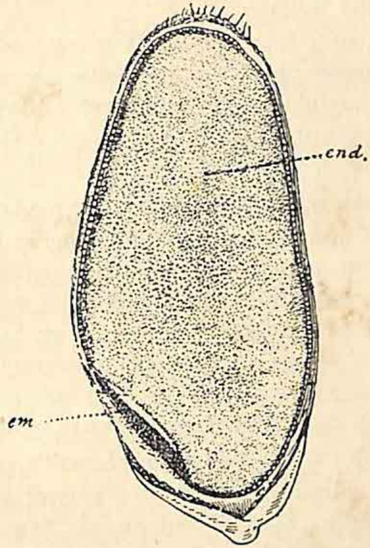

Fig. 47. Section of rice showing the endosperm and the embryo : *end*, endosperm ; *em*, embryo

Questions

1. Describe the germination of seeds of the pea plant.
2. In what way does the life history of the pea differ from that of the rice ?

CHAPTER V

THE ROOT

Function of the roots—

Plants procure food by sending out roots to the soil. The roots absorb there the requisite ingredients. Earth contains various chemical substances or mineral matters. These are dissolved in water and the solution passes into the roots by a process called *osmosis*.

If two solutions having different strengths with regard to the amount of matter dissolved in them, be kept separated by a parchment membrane, one of the solutions will pass into the other in spite of the presence of a partition wall separating the two and having no pores or holes in it. The process is called osmosis. Osmosis plays an important part in the suction of water and of dissolved matter by the roots, and in sending them up through the stem into the leaves.

Since the plant cannot move about in search of food, it is essential that roots should spread underneath to obtain sufficient amount of food from there. The roots spread out in the soil as the branches of the stem do in air.

Characteristic of root—

The root is generally that part of the plant which goes down into the soil. It is called *descending axis* while the stem which rises up above the ground, is called the *ascending axis*. The root draws away from light, and is pale in colour. The stem moves towards light, and is greenish in colour. The root does not bear any flower, bud or leaf. A root increases in length by the multiplication of cells at its tip. The growing point of the root is covered by a sheath. The sheath protects the growing point as it makes

its way through the soil, and is known as the *root-cap.* At a little distance from the growing tip, there are root-hairs. They look like fine and delicate threads and enter the finest interstices between the soil. They increase the absorbing surface of the young roots, and so, they should not be damaged in transplanting a plant from one place to another. A few plants have roots which not only absorb food from the soil but store it up. The roots in such cases are large and fleshy. Starch, fat and sugar occur as reserve food in the roots. Radish, carrot and sweet potato have food stocked in their roots for their own future use. The storage is done in the early part of their life. Later, the flowers and fruits are put forth and these grow at the expense of the reserve food which is thereby used up. These plants, therefore, are harvested, before they run to flower and seed, and their stock of reserve food is lost.

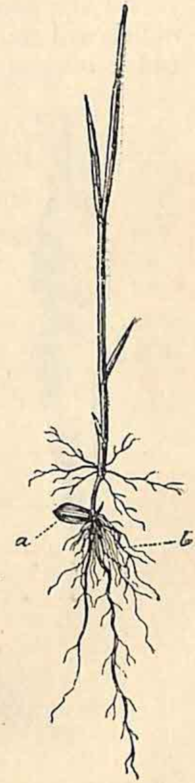

Fig. 48. Seedling of rice plant
a, Germinating seed
b, Fibrous root

Roots are of various types. In radish or 'Moola', the root is long and tapering (Fig. 49). It is conical in carrot or 'Gajar'. In turnip or 'Salgum', the root is dilated at the middle and tapering at the terminal end.

In 'Sata-moola' and 'Ranga-aloo' the roots arise in thick bunches.

All the above examples of roots are grouped together as the primary or tap root, and differ from the second type called the *fibrous root.* In the second type the primary root is replaced by a cluster of slender roots. Grasses and rice plants

8

have fibrous roots (Fig. 48). These roots are not thick and fleshy as in radish or carrot.

All the above types of roots are developed from the radicle and are, therefore, classified as the *true root*. Roots which originate not from the radicle but from stems or

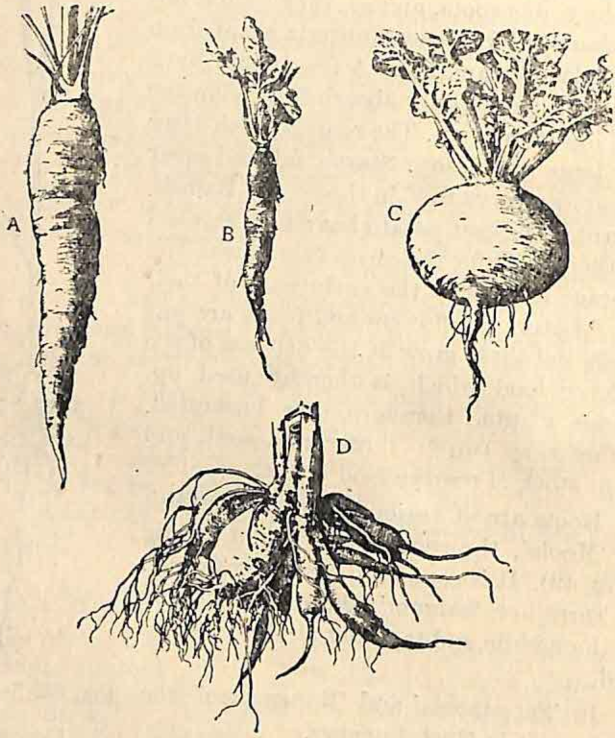

Fig. 49. Various types of roots
A—Carrot or Gajar, B—Radish or Moola (fusiform)
C—Turnip or Salgam (napiform), D—Tuberous root

leaves or from other parts of plants, are called the *false* or *adventitious roots*.

In 'Gajapipul' which climbs upon other trees, roots arise from the stem and help the plant in remaining attached to its support.

The adventitious roots which thrive in air are called *aerial roots.* Most of the orchids cling to branches of trees by the ærial roots. The Banyan tree produces roots which remain suspended in air. These are the ærial roots. When these reach the soil they go underground and branch there like other roots, but the part above the ground increases in thickness with age and looks like a stem. These lends additional support to the branches or the stem. In 'Kia' or screwpine, the ærial roots are given off from the stem and these roots support the stem like stilts. Many trees such as the Almond show their roots above the ground as flat buttresses which enable the plants to stand firmly.

Questions

1. Distinguish between the tap and fibrous roots.
2. Narrate the functions of roots.
3. What are the different types of roots you know ?

CHAPTER VI

STEMS

The stem arises as the prolongation of the plumule of the germinating seed, and usually shoots high above the ground. The stem generally has not to make its way through the soil ; its growing point therefore always lacks a protecting sheath like the root-cap. Its function is to conduct liquids up from the roots to leaves and down from leaves to other parts. It is not provided with fine

and delicate root-hairs. The stem unlike a root is usually green in colour and bears buds, leaves, flowers and fruits.

Buds are the growing points of the stem and may be grouped as stem, leaf and flower buds according as they develop into a stem or blossom out into leaves, or open out as flowers. They are found at the terminal end of a growing stem or the shoot, and occur also at the side of the stem or its branches.

The bud at the terminal end of the stem is called the *terminal bud*, and by its growth the stem elongates. Close to the growing shoot, stand the leaf-buds which unfold into leaves.

The angle which the stalk of a leaf makes with the stem or its branch, is called the *axil* or the armpit, and a bud situated at the upper angle of the axil is called the *axillary bud*. The axillary bud is at the side of the stem and grows into a branch. The axillary buds of a branch give rise to sub-branching and a many branched tree like the banyan is produced. If the axillary buds remain undeveloped a branchless stem results as in the palms.

Stems are usually round. In 'Tulsi' plants the stems are square in cross section.

In a few plants the stems are flattened and look like the leaves. They are fleshy too, and subserve the function of storing moisture. In the prickly-pear or 'Phanimonsha', the stems are of this type.

In the Indian corn plant and in the bamboo the stem shows distinct swellings or joints at intervals. These joints are called the *nodes*, and parts between the nodes are called the *internodes*. The plant increases in height by adding the nodes one after the other. The leaves also spring from the nodes.

Now leaves want air and light. The stem shoots high up so that the leaves are put into a favourable

position with regard to air and light supply. If it is to maintain a lofty position, the stem should be strong.

In teak and mahogany trees which reach great heights, the stem contains inside wood which is a strong substance and can bear the weight of the branches, or can withstand the force of wind and rain. The wood is formed by the modification of cells and conducts the nutrient food in solution. In a cross-section the wood is found to be arranged in rings which are annually laid, and by the counting of these rings the age of a tree can be reckoned. Inside the wood and running through the centre of the stem, is a pulpy thing called the *pith*. It forms a store-house of food material of the plants. In young plants the pith is clearly seen. It cannot be distinguished in old trees. The wood is covered on the outer side by the bark which protects the plant from sudden changes of temperature, rain and other injurious elements. Often the bark is shed and periodically renewed.

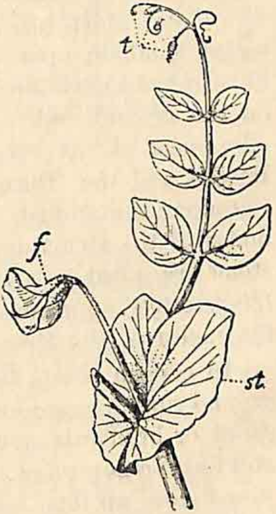

Fig. 50. the pea plant
t, Tendril *f*, Flower
st, Foliaceous stipule

In palms and bamboos which are giant grasses, the stem is hollow and the wood is neither arranged inside into concentric rings nor covered by a bark. The hardest and densest part of the wood is on the outside.

Now if a stem be weak and not strong enough to stand upright, it needs some sort of support. The weak-stemmed plant seeks therefore a strong plant or a stick to lean upon, and adopts various methods to raise itself up.

Plants like 'Shim' (*Dolichos*), 'Barbati' (*Vigna Catjung*) twine themselves round the support by twisting their own stem. Others like the Pea or 'Matar' (Fig. 50), the 'Lau' or the bottle gourd, climb by throwing round the support curling branches called *tendrils*. The tendrils are thread-like and have no leaves or buds. Plants like the 'Shiakul' (*Zizyphus*) and the rose, climb by means of hooks or spines which are pointed backward to prevent the slipping of the stems from the support.

'Ulat-chandal' (*Gloriosa superba*) climbs by means of their leaves which are spirally wound. 'Pan' or Betel vine, maintains its hold on the support by sending out adventitious or false roots from its stem.

Plants which cannot stand upright and have not learnt climbing upon others, have the best chance of a life if they lie down and trail on the ground. By spreading on the ground and not rising up they gain at least the advantage of not being swept away by wind. 'Puin' or Basella and the 'Durbaghas' (*Cynodon dactylon*) creep or run along the ground. In the latter, roots arise from the nodes of the stems and pass to the soil. Such creeping stems are called *runners* or *stolons*. Often as in 'Thulkuri' (*Hydrocotyle*) new roots and new shoots strike wherever the nodes of the stem touch the ground.

In certain plants the stems instead of trailing on the ground run underground. From the underground stems, a shoot or branch is given off which rises above the ground and forms a new plant. In certain plants the underground stems store up food materials. In difficult seasons when roots cannot take in water as in drought, the plants fall upon the reserve food stored in the underground stems. The underground stems are known as the *root-stocks* or *rhizomes* and can be distinguished into nodes and inter-nodes. Roots are given off from these stems. The

underground stems are not green in colour and therefore apt to be mistaken for roots. But they differ from the roots in having buds and leaves which do not arise from roots. From the buds on the underground stem, new shoots arise and these come up above the ground and bear leaves, flowers and fruits. When these die, fresh ones are given off. The leaves on the underground stems are not exactly like the leaves exposed to the sunlight and air. They are not green and are very small; they are known as *scale-leaves* or *scales*. In some cases these are fleshy having an abundant store of reserve food in them.

The underground stems are of various types.

In 'Ada' or ginger, 'Halood' or turmeric, the underground stems are long and grow horizontally. They die at one end, and grow at the other. They send out periodically shoots above the ground. Round scars are left where the upright shoots grew and died in the past season.

Canna has thick underground stem and sends shoots upwards with leaves and flowers.

In the potato plant the underground stem is swelled at portions to lay up nourishment for the support of the plant (Fig. 51). The thickened swellings of the stem are called *tubers*. The potato is a tuber and not a root; nor it is a fruit. On the tuber, spots like eyes and eyebrows could be seen. The eyes are buds and if planted would develop into ærial shoots. The eye-brows are scales or underground leaves.

In 'Ol' (*Amorphophallus*) the stem runs beneath the ground. It is thick and round. It is known as the *corm*. If it is cut it is found solid like a stem.

In onion and garlic the part we make use of is known as the *bulb*. It remains underground and sends out roots. The bulb is composed of soft, fleshy and juicy

leaves. These leaves are called scales and contain food material stored in for future nourishment of the plant. During the flowering season, a shoot is given off from the centre of the bulb, and it bears flowers.

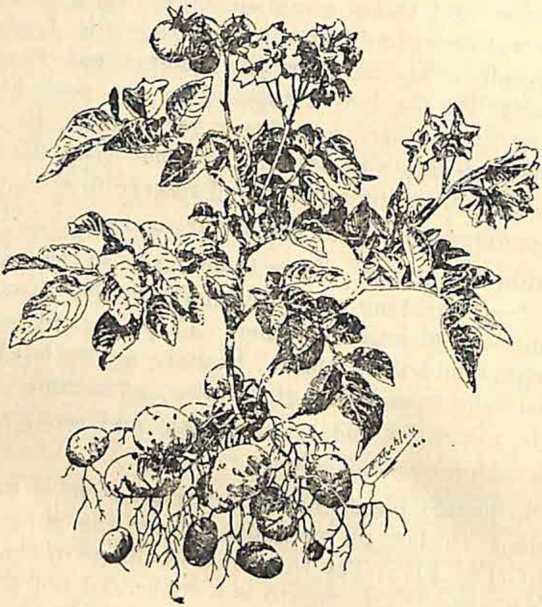

Fig. 51. Potato tubers

Questions

1. Compare the functions of stem and root.
2. How would you distinguish an underground stem from a root ?
3. Give a classification of the different kinds of stems.

CHAPTER VII

LEAVES

The materials absorbed by roots from the soil are a kind of raw food which need further preparation or cooking. The preparation is done in the leaves which therefore are spoken of as the kitchens of plants. But no fire is required. The solar energy is absorbed by the leaves, and by it the raw food is converted into prepared food which travels back from leaves to stem and to such parts as need nourishment.

The food materials such as nitrates and phosphates absorbed by the roots from the soil, do not contain carbon. The latter element, however, is required by the plant for proper nourishment and building up of its body. It is obtained from air by the leaves. Air contains carbon dioxide gas. Leaves take in air and thus get carbon dioxide. From the latter the carbon is seized by the leaves and oxygen is liberated. The carbon with the help of the sun's rays, is changed into starch and other plant-foods rich in carbon. This process of manufacturing starchy food in the leaves by sunlight is called *photosynthesis*.

Now chlorophyll present in the green leaves plays an important part in this process. It is as essential as the sunlight, and one cannot act without the aid of the other. The sun's rays are caught as it were by the leaves, and the process of elaborating food by the green leaves goes on in the daytime but stops for want of sunlight at night. The transportation of prepared food from the leaves to other parts, however, continues even in darkness.

It should be noted that during photosynthesis, carbon

dioxide is taken in by the leaves and oxygen is given off. Now animals breathe in oxygen from air and breathe out carbon dioxide. At daytime plants appear therefore to be doing the very reverse of what animals do in breathing; but the above gaseous exchange during photosynthesis between the plants and the surrounding air, should not be regarded as a kind of breathing. Breathing is a different process. Plants at all times breathe in oxygen from the air, and give out carbon dioxide as all animals do in respiration. It is remarkable, however, that the products of respiratory activity in plants stand opposite to that of the photosynthesis and this is an advantage. The carbon dioxide given out by plants finds its way back into the leaves as soon as it is liberated, and is assimilated as food during the daytime. The liberation of carbon dioxide by plants while photosynthesis goes on, is therefore not perceptible.

At night photosynthesis stops for want of the sunlight, while respiration of plants goes on. Therefore, the elimination of carbon dioxide is more free at night.

All parts of plants such as flowers, seeds, breathe both day and night, but leaves do most of the breathing.

Leaves have breathing pores scattered over their surface. The breathing pores are called *stomata* and are more numerous on the under surface of leaves than on the upper surface. They act like our nostrils in drawing air into the leaves. They are closed and opened as necessity arises. Carbon dioxide is given out through these apertures.

Leaves have not only the double function of respiration and assimilation of food, but also help in the evaporation of surplus water from the plant.

The nutrient materials present in the soil could be drawn

in by the roots only when they are in solution. A large quantity of water is required to make a proper solution of these earthy materials. So the roots take in more water than the plant is going to use, and this water passes up to the leaves carrying the dissolved substances. The excess of water not needed by the plant evaporates through the stomata. This process is called *transpiration*.

In a hot or windy day, water rapidly evaporates from leaves, therefore more loss of water may take place during such times than the plant can afford. Water is needed not only for transportation of food but also for keeping the body of the plant turgid. To guard against an excessive loss of water, leaves assume at such times a dropping posture so as to diminish the surface of leaves for prevention of rapid evaporation of water.

A typical leaf consists of an expanded portion called the *blade* or *lamina*, and a small stalk. At the junction of the leaf-stalk with the stem, there are small tiny leaves called *stipules*. Often the base of the stalk broadens out into a sheath as in the plantain leaf (Fig. 52). In palms the sheath embraces the stem.

Fig. 52. Plantain leaf
a, Sheath
b, Petiole
c, Blade

In the majority of plants the sheath is absent, and in a few instances the stalk is wanting.

The leaf-blade is of various forms. It is long in grasses and rice plants, oblong in plantain, and egg-shaped in banyan. The leaf is heart-shaped in 'pan'.

The tip of the leaf may be blunt, or pointed as in 'Aswathwa' (*Ficus religiosa*). It is notched in 'Amrul' (*Oxalis corniculata*).

The margin of the leaf is wavy in 'Debdaru' (*Polyalythia*)

or cut into teeth or serrated as in 'Jaba' or Chinese Rose (Fig. 53).

If a single leaf is borne on a stalk as in the above examples, it is called the *single leaf*. If there are several leaves on a common leaf-stalk, they are called *compound leaves*. It seems as if the compound leaf has been derived from the simple by being deeply cut into lobes. In compound leaves each single leaf is small and is called a *leaflet*. The leaflets may be arranged as in 'Bael' (wood apple) or in a row on each side of the axis of the leaf, feather-like as in the Tamarind tree or as in 'Sajina' (*Moringa pterygosperma*) (Fig. 54). The Pea plant also has compound leaves (Fig. 50). In certain cases the leaflets are so arranged as to radiate like the fingers on a hand. The 'Simul' or silk-cotton tree has compound leaves of the above type (Fig. 55).

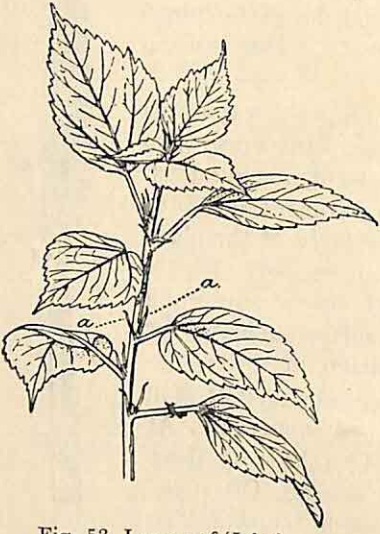

Fig. 53. Leaves of 'Jaba'
a, a, Lateral stipules

The soft portion of the leaf-blade is supported by a hard framework which runs through it like the ribs. The ribs are called *veins*. They are, however, different from veins or blood-vessels of animals, although they conduct the sap which nourishes the plant.

Veins in the leaves may run as follows :—

A midrib runs through the centre and veins spring from this, and later divide into a net-work. Mango, and rose have this type of venation.

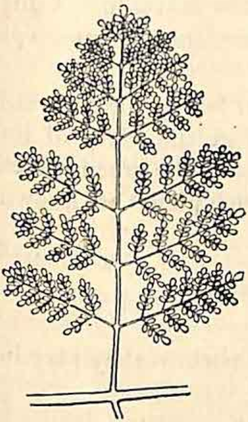

Fig. 54. Compound leaves of 'Sajina'

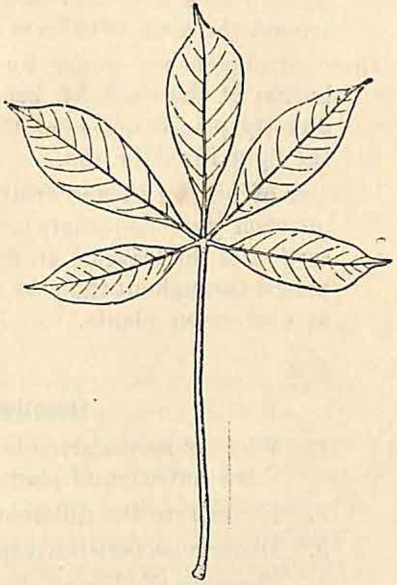

Fig. 55. Leaves of the silk cotton tree

Principal veins may also start as in palm-leaf from the leaf-stalk and spread through the blade and then branch into a net-work. In rice and grasses all the veins run parallel to one another and do not branch to form a net-work as in the previous types.

Leaves are placed on the stem or its branches in a definite order. In certain plants, as in the lime tree, leaves spring from alternate sides of the stem.

and each node or joint contains a single leaf. The leaves in such a case, are called *alternate leaves*. In others, two leaves arise from the same level from the two sides of the stem. They are called *opposite leaves*. In a few other plants, leaves are so arranged around the stem as to form a *whorl*.

These arrangements secure for the leaves equal distribution of the sunlight, because the leaves not being directly placed one over the other, do not intercept the light from the top.

In most of our forest and fruit trees, leaves die and fall off each year and scars are left at the place of insertion of the leaves. In a few cases the green leaves persist throughout the year, and such plants are known as ever-green plants.

Questions

1. Why are leaves green ? What part do they play in the nutrition of plants ?
2. Enumerate the different functions of leaves.
3. Distinguish between respiration and photosynthesis.
4. Compare the leaves of the pea plant with those of rice.

CHAPTER VIII

THE FLOWER

Flowers are the reproductive organs of plants. The most conspicuous parts of flowers are the *petals*. The flowers which open by day, usually, have gay coloured petals while those which open by night have white petals.

Outside the petals is a whorl of leaf-like green structures called the *sepals* or the *calyx*. Enclosed within the petals is found a number of stiff filaments each of which carries at its tip a small case or leathery box. This contains inside powdery grains called the *pollen*. The pollen grains are the male reproductive cells. These are liberated as the pollen case bursts open.

A slender tube called the *pistil* stands at the centre of the flower inside the petals. This tube ends above in a swelling which has a sticky surface. This is known as the *stigma*. The base of the tube widens to form a case called the *seed-box* or the *ovary*. The ovary contains the ovules or female reproductive cells.

Fertilization—

If the pollen falls on the stigma, it passes in through the pistil in the form of a fine tube so as to reach the ovule. The male and female cells unite and the ovules change into seeds. This process of union ending in the seed formation is called the *fertilization*. Ovules would not develop into seeds unless fertilized by the pollen grains. The fertilization would not be possible if the pollen grains did not fall on the stigma. The process of transference of pollen to the sitgma is called *pollination*.

Flowers are of various kinds. The Pea-flower has five petals which are unequal in size. Outside the petals is a whorl of small leaf-like structures called the *calyx* or the *cup*. The pollen bearing filaments are five in number, four of which, however, are united at their bases. The pistil is at the centre of these filaments. In 'Datura' (Fig. 56) the pollen bearing filaments are five in number and lie protected within the petals. The pistil is at the centre. The petals are five in number and are united by

their edges to form a funnel. The sepals encircle the petals. In roses the petals are expanded.

The petals are of various forms and the number of the pollen bearing filaments is different in different plants.

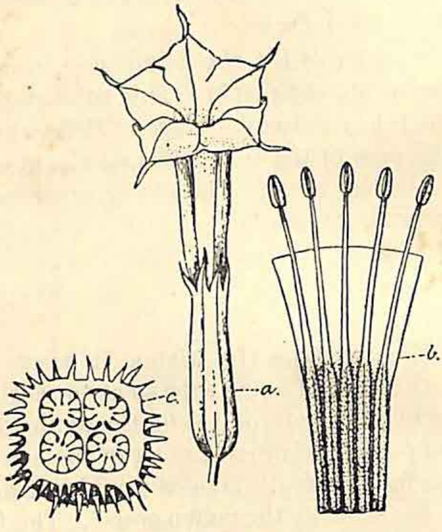

Fig 56. 'Datura' flower
a, Whole flower with tubular calyx below and corolla above
b, Corolla cut open showing stamens
c, Four-celled ovary cut open

A flower may have all the parts or may be lacking in some. In the pea and 'datura' all the parts are present and the flower is said to be a *complete flower*.

The most essential parts in a flower are pollen bearing filaments called the *stamens*, and the ovule bearing tube called the *pistil*. Where both these are present, as in the pea-plant and the rice, the flower is both a male and a

female. If the pistil is wanting but the stamens are present, the flower is said to be a *male flower*. If the stamens are absent but the pistil is present, it is a *female flower*.

In 'Papaw' the male flower is on one plant and the female in the other. In some palms a few flowers are male while others are female, but both occur on the same plant.

Pollination of flowers—

The transference of pollen grains from one flower to another, is mostly effected by the agencies of wind, insects and birds. If the pollen grains are light and dry they can easily be blown by wind from one flower to another. The stigma is hairy and is so placed that it can easily catch the wind-blown pollen. The flowers of grasses depend on wind for the transference of pollen to the stigma and so they are coloured or scented.

The flowers which depend on insects for pollination, have gay colours or sweet scents for alluring them. The insects such as bees and butterflies dive down into flowers in search of nectar. As they move from flower to flower, they carry the pollen from one flower to the stigma of the other of the same species, and thus secure the pollination of flowers.

Questions

1. Distinguish between pollination and fertilization.
2. Name the different parts of a flower you have studied.
3. In which part of the flower is the seed produced ?
4. Name some flowers which open by day and which open by night. Describe their colour and shape.

CHAPTER IX

FRUITS AND SEEDS

After the fertilization the ovary or the seed-box of the pistil grows big, and other parts of the flower wither away. The seed-box changes into the fruit. Often other parts of the flower persist and take part in the formation of the fruit. In 'Chalta', 'Sal' and 'Sagoon' for instance, the calyx becomes fleshly and encloses the seed-box. In most cases, as mentioned above, the ripened pistil becomes converted into the fruit. The essential parts of a fruit are the seeds which will start the life of the next generation. Sometimes it happens that the fruit is not the product of a single flower but is composed of a number of flowers aggregated together. The jack-fruits, 'aswatha' are examples of this type.

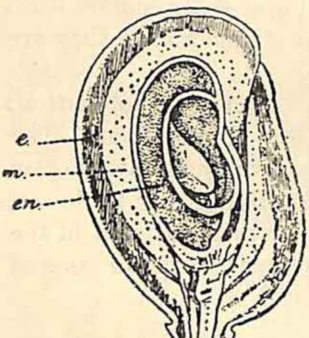

Fig. 57. Section of Mango
e, Epicarp *m*, Mesocarp or the middle coat
en, Endocarp (stone)

A fruit consists of three coats derived from the wall of the ovary or the seed-box. In mango (Fig. 57), the skin represents the outermost coat. Below this is the fleshy pulp which we eat. This represents the middle coat. The innermost coat is hard and tough and is known as the *stone*. It encloses the large seed. In date, the innermost coat is a thin membrane enclosing the seed.

In cocoanuts the middle coating of the fruit is well-developed. Its inner coating is hard and encloses the seed.

Fruits may be divided into fleshy and dry fruits. Mango is a fleshy fruit.

The dry fruits contain no fleshy layer. The nut is a dry fruit. Some of the fruits burst and set free the seeds. The pea-fruit (Fig. 58) called the pod bursts on the two sides. Others do not burst to liberate the seed. Cocoanuts come under this type.

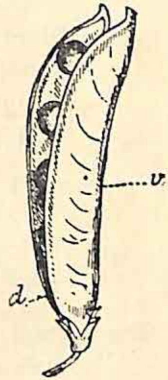

Fig. 58. Pod of pea
v, Ventral suture
d, Dorsal suture, along which the fruit bursts open to liberate seeds

If the seeds fall on a suitable ground they develop into seedlings. Seeds produce weaklings or die if the soil be unfavourable for germination.

It is necessary therefore, that not only seeds should find a favourable ground, but should be scattered far and wide so that they find a virgin soil where competition of life is less. For the journey far and wide, fruits and seeds are dependent on outside agents. Fruits of 'Sal' or *Soria* have wings and are carried easily from one place to another by wind. In cotton the seeds are provided with hairs which help them in floating through air. Fruits may be carried by ocean currents. The cocoanut is carried away by water and is protected by a thick fibrous coating from being dashed to pieces by waves. Some fruits or seeds are distributed by animals or by men. Many fruits and seeds are provided with hooks and spines, by means of which they cling to the skin or furs of animals and thus are transported from place to place.

Birds and animals which feed upon fruits may scatter wide the seeds.

Questions

1. What is the distinction between the fruit and the seed ?
2. Mention a few edible fruits and note the number and arrangements of seeds in them.
3. Explain how seeds are liberated in the pod of the pea-plant.
4. Give an account of the different modes of dispersal of seeds.

CHAPTER X
ZOOLOGY

The animal kingdom—

Animals are classified into groups or *phyla*. Animals having their body made of a single cell, are known as *unicellular* animals. They are microscopic in size, and a drop of water may contain a million of them. They have no special organs for respiration, digestion or reproduction. They represent the simplest forms of animal life and are grouped together under the *phylum Protozoa*. Amoeba, bellanimalcules, malarial parasites come under the above phylum. Amoeba, (Fig. 59) is a minute animal found in mud or in a pool ; the entire animal is formed of a speck of protoplasm. It constantly changes its form by the flowing out of its protoplasm in different directions, and by the same process it moves and engulfs food.

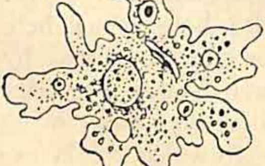

Fig. 59. Amœba

The great majority of animals are composed of innumerable cells and are known as *multicellular* animals. They fall under several groups or phyla.

Sponges have a number of apertures on their body and

are grouped under a separate phylum. They get in food by driving in a current of water into their body.

The coral-forming animals which look like diminutive-branched trees in the floor of the shallow sea, and the jelly-fishes (Fig. 60) which have the shape of an umbrella and float on the sea, come under the same phylum. They have a single cavity inside the body, opening by an aperture called the mouth ; there is no separate anal aperture. They kill their prey by shooting out fine barbed threads.

The earthworm swallows earth and crawls on the ground. The leech gorges itself with blood of its prey and exhibits a looping movement. The food-canal is well-developed in them. Both have a body divisible into rings called *segments*, and are included in the phylum *Annelida*.

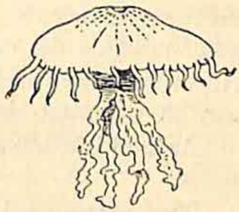

Fig. 60. Jelly-fish

Prawns, crabs, centipedes, insects, spiders have their body invested with a hard and rigid covering. The body is divisible into head, thorax and abdominal regions. They have jointed legs and are classed as *Arthropoda*.

Oyster, snail and cowry have a soft body protected within a hard shell. They come under the phylum *Mollusca*.

The above examples lack any internal skeleton made of bones and are known as *invertebrates*.

Fishes, frogs, snakes, birds, dogs, cows, are known as *vertebrates*, by virtue of having a backbone inside the body.

All of them have a chambered heart situated on the ventral side below the gut, and a central nervous system above the gut.

Vertebrates are subdivided into several classes. The fishes have fins which are supported by spines or rays. They breathe by gills.

Frogs and toads have a moist, naked skin and are known as the *Amphibia*. They can live both in land and water. Newts and Salamanders are tailed *amphibians*.

The lizard, crocodile and snakes have a scaly body and are known as *reptiles*.

Birds are characterized by the possession of feathers and have no teeth.

The mouse, cow, horse, dog, monkey and man are classified as *mammals*. Their body is covered with hair, and the mother suckles the young. The bat is a flying mammal, and the whale and porpoise are known as aquatic mammals. All of them whether living on land, water or flying on the air, have similar characters. They respire by lungs.

Animal life affects our lives and welfare in innumerable ways.

The cattle, silkworm, lac-insect, bees are beneficial animals. Pearl is produced by pearl-oyster. The locust moves in swarms and destroys crops. Flea, mosquito and house-fly spread diseases. They are injurious. The scorpion stings by the tail end. The cobra, russel-viper and krait are venomous snakes. The rat-snake is non-poisonous and destroys field mice.

The diverse types of animals are considered to be the descendants of a common ancestor of a simpler type that lived long long ago. Children do not exactly resemble their parents, and no two children of the same parents are exactly alike ; therefore, it is conceivable that as the conditions of the earth changed, the descendants gradually changed and assumed new forms. This process has gone on for millions of years and resulted in the evolution of the wonderful animal world. All the animals, therefore, are related to one another by ties of blood. This is the doctrine of descent with modifications, and is known as the *theory of evolution*. It was the great Darwin who explained clearly

how this takes place, and the theory of evolution has become synonymous with his name.

The object of classification is to express the degree of relationship between different animals. Each phylum is divided into classes and classes are subdivided into orders, orders into genera, and a genus into species. A group of individuals having similar characters is put under one species. The cat is a species of animals. The tiger is a species ; the dog is a species. The cat and the tiger have retractile claws. They are put under one genus. The dog is put under another genus. All the three are carnivorous and have flesh cutting teeth. They are put under one family. The cat is named *Felis domestica.* The first word indicates the genus and the second the species.

Questions

1. How would you classify the animals ?
2. Compare the body of an invertebrate with that of a vertebrate.
3. Describe the habits of some common animals you have observed.

CHAPTER XI
THE EARTHWORM

The little spiral mounds of earth scattered on lawns and open fields are known as "worm casts". They are the faeces of the earthworm. The earthworm (Fig. 61) eats the earth containing organic matter, takes in the organic portion and the residue comes out as the "cast". It is a defenceless creature, and its safety lies in leading an underground life. But it has no hand or foot to help it to dig a hole for

itself. It applies the pointed tip of the body bearing the mouth against soft soil and eats the earth as it burrows.

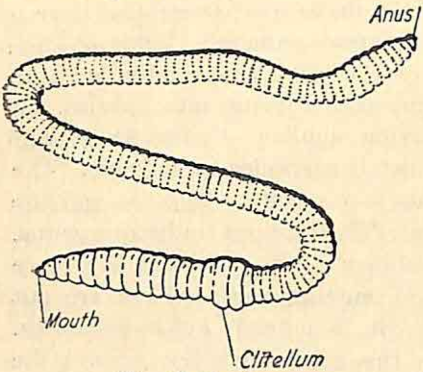

Fig. 61. Earthworm

In its boring operation it turns up the soil from underneath, and thus ploughs the land to the benefit of man. Generally it keeps itself within its burrow in the day-time and ventures out at nightfall. But during rains it is found at all times in the open. It has no eyes, but it perceives the difference between light and darkness. If a light is suddenly turned on it, it withdraws into its burrow. It also contracts its body if touched.

It crawls out at night in search of food and moves by elongation and contraction of its body. In its forward movement, it is aided by minute pegs called *setae* situated on its body. These are driven against the soil and give a grip in movement.

It drags pieces of vegetable leaves and twigs into the mouth of its burrow and feeds on them without exposing itself to its enemies. It is fond of savoury food like the onion and picks them out from other bits of vegetable matter.

It has no lung or gill. Its skin is soft and moist and carries on the respiratory function by absorbing oxygen from air and eliminating carbon dioxide.

The earthworm is placed under the phylum *Annelida* which is derived from the word *Annulus* or ring. Its body can be compared to a long flexible pipe composed of several smaller pieces joined end to end, and lines of junction marked by circular grooves. Each such separate piece is called

a segment; there are 100-120 segments in our common earthworm. Its body is cylindrical. The mouth end of the body is called the *anterior*, and the opposite end the *posterior* region. The surface of the body in contact with the earth is the ventral surface.

If a narrow tube runs through the hollow of a big tube we have a tube within a tube. The earthworm's body is built on the same plan. The outer tube or casing represents the body wall, and the inner tube, the digestive tube. The space between the outer and the inner tube is called the body cavity or *coelom*.

The body cavity contains a fluid which comes out through small pores on the dorsal or upper surface of the body and keeps the body clean. The fluid is ejected if the skin is irritated, say, by methylated spirit. Corresponding to each groove on the external surface of the body, there is an inner partition or *septum*, and the coelom or the body cavity is thus divided into a series of compartments (Fig. 62). The body of the earthworm, therefore, is said to be

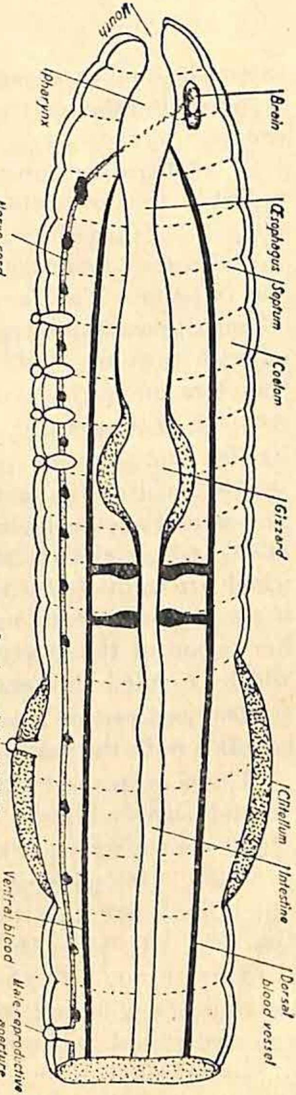

Fig. 62. Earthworm cut to display some of the internal organs: the anterior portion of the body shown only

internally and externally segmented. Such a mode of segmentation of the body is peculiar to animals of the Annelida group.

The digestive tube (Fig. 62) runs straight from the mouth to the anus, which is situated at the blunt end of the body. It is divisible into several parts : these are called the *pharynx*, *œsophagus*, *gizzard* or grinding stomach and the *intestine*. The food is first sucked into the pharynx whence it passes into the oesophagus where the food is treated with various secretions. The earthworm has no teeth; therefore the food is crushed into finer bits by the grinding stomach or the gizzard. The food is now fit for absorption by the long intestine.

The blood of the earthworm is red in colour owing to presence of haemoglobin in the plasma or liquid portion of blood and circulated through long tubes called *bloodvessels* which are connected with each other by cross branches. A nerve cord containing nerve cells runs below the gut and in the region of the pharynx, rises up and forms a swelling which is called the *brain*.

The earthworm is a *hermaphrodite*. The same worm contains both the male and female reproductive organs.

There are several apertures which occur in pairs on the ventral surface of the body—towards the anterior end. These are concerned with reproduction.

A few segments posterior to the mouth there is a band which looks like a swelling. The band is called the *clitellum* (Fig. 61, 62). On its ventral surface there is an aperture through which eggs come out. The clitellum at the time of egg-laying, secretes around it a capsule in which eggs are stored. The capsule is slipped out of the body and is deposited on the earth a few inches below the ground. The development of eggs into young worms takes place within this capsule.

Questions

1. Describe the peculiarities of the earthworm's body.
2. How does the earthworm secure its food and protect itself against its enemies ?
3. Describe the habits of the earthworm.

CHAPTER XII

INSECTS

The body of an insect is divisible into head, thorax, and abdomen. The head carries a pair of *antennae* or feelers. The antenna is composed of numerous joints and bears hairs, some of which are the seats of the sense of smell and touch. Insects feel objects by touching them with the antennae, and in distinguishing different objects, depend more on the sense of smell and touch than on the organ of vision. But, far from being blind, they have eyes in hundreds. These are grouped in two patches, one on each side of the head, and form what is called a *compound eye*. These eyes, however, have no power of accommodation, all the parts being fixed, and the vision is quite different from that of a vertebrate. By the compound eyes the insects quickly discern the minutest movements of objects. The night visiting insects possess, in addition to the compound eyes, three little shining eyes called *simple eyes*, which are round in shape, and occur isolated in the top of the head. These help them to follow the direction of light.

The thorax carries three pairs of jointed legs (Fig. 65). In addition, the thorax in butterflies and bees, bears two pairs, and in mosquitoes, one pair of wings. The wings of butterflies differ from those of ants and bees, in texture and shape.

The worker ants as well as numerous other insects have no wings at all (Fig. 64).

The abdomen in bees and in some ants bears a sting. The male bee or drone is without a sting.

The insect has no nostrils, or lungs. Usually ten pairs of apertures called *spiracles* or *stigmata*, are distributed on the sides of the thorax and abdomen. They lead into air pipes or *tracheae* which directly supply air to the tissues. These represent the respiratory organs of the insect. The digestive and nervous systems are well developed. The brain is more complicated in structure than that of the earthworm. The heart is in the form of a long tube.

The butterfly—

The butterfly is a day-visiting insect, hovering over flowers. At rest, it holds up its brilliantly coloured wings high over its body like a banner. The moth, a night-visiting insect, resembles the butterfly except in colour and the shape of the antenna. It keeps its wings, unlike the butterfly, folded over its body when at rest.

The butterfly sucks nectars of flowers by shooting out deep into the flower cup a long mouth-tube called the *proboscis*, which lies coiled like a watch spring in the mouth (Fig. 63). The butterfly has no powerful biting jaws, and is incapable of inflicting any wound to the plant or animal tissue ; while innocent and attractive at the winged or perfect stage, it is a danger to the plant life at the caterpillar or larval stage.

The female butterfly lays hundreds of eggs on the plant. The time the eggs take to hatch, varies in different species, and is dependent on seasonal conditions. A tiny caterpillar hatches out of the egg, and begins to eat. Often the first food it takes, is the broken egg-shell. It then starts to devour the leaves. It is a ravenous eater. After a time

it casts off its old skin, and a new skin is formed. The shedding of the skin is called *moulting*. The old skin is hard and rigid, and does not allow the insects to grow unless it is split and cast off. The new skin is soft and elastic, and allows the body to increase in size, before it is hardened again like the old skin. Growth therefore follows moulting. The caterpillar continues feeding on the leaves; it periodically moults and grows. It should be noted that moulting does not take place once the perfect stage is reached. The butterfly does not, therefore, increase in size like the larva.

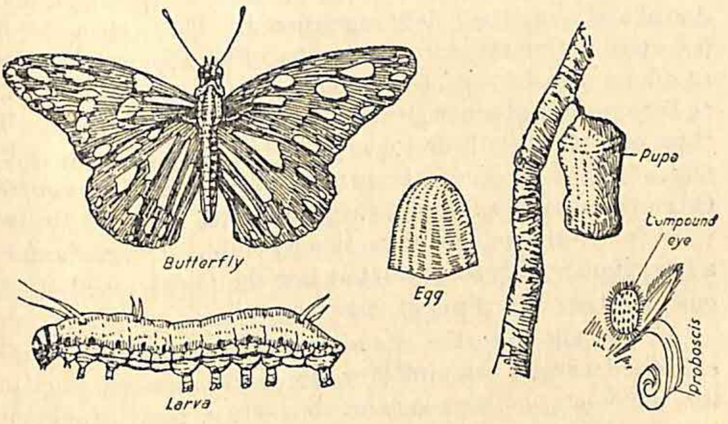

Fig. 63. Butterfly—egg, larva, pupa, head with proboscis

The young one not dependent on its parent for livelihood, or protection, is known as the *larva*. The larva means a mask, and indeed its parentage and future are masked. It does not in any way resemble its parents. The caterpillar which is the larva of the butterfly, looks more like a worm than an insect. It does not possess the three pairs of jointed legs or wings, characteristic of insects.

Some fleshy outgrowths on the body on the ventral side aid in movements (Fig. 63). The head is distinct and possess powerful jaws for cutting leaves, and the trunk is segmented. There comes a time when the larva ceases taking any food, stops growing, and becomes inactive. This happens before it passes into the next stage called the *pupa* stage. The larva shrinks in size and the pupa is formed within the larval skin which is ultimately lost. The pupa means a baby swathed in its cradle. It does not take any food and save for a little twitching of its body when touched, it remains motionless. During this quiescent stage, a great transformation of body takes place. Old tissues are broken down, and a new body is reconstructed. The perfect insect is formed within the skin of the pupa which thus acts like an envelope or a casing of the coming insect. In the pupa, rudiments of antennae, legs and wings are visible but all these are stuck with or soldered to the body and are not free. The pupa is also known by the name of *chrysalis*. Often the chrysalis is found suspended with the head downward from a tree or a leaf by a slender stalk. It remains for a long time at this stage, and at last the pupal case bursts out, and the winged insect emerges.

In the silk-moth the life-history is similar. The larva eats the leaves of the mulberry tree, and before passing to the pupal stage, spins around its body a mess of silken threads. The threads come out of the mouth as sticky secretions, and on drying up form the cocoon or the pupal case. The pupa remains enclosed within the case on being transformed into the winged form, cuts the cocoon and comes out. The life history is completed within a month and a half. Silk is obtained by unreeling the cocoon before it is cut by the emergent moth.

The insects which are divisible into these three stages of life and pass through the changes enumerated above in

course of their development, are said to undergo complete metamorphosis.

Social insects—

The ants and bees are social in habit. A colony of them containing males, females, workers and children live together in a common nest, and constitute a community. Members of the same community know one another and live in amity. A division of labour exists between them; but the heaviest duty falls on the *workers*. The males are idlers, and are known as *drones*. The whole concern of the females is to produce eggs. As the future of a community depends on new births, the females are attended to by workers, and are spoken of as *queens*. The queen does no work and does not even take care of her own brood. The workers look to the welfare of the colony and work disinterestedly for the common good. They are nurses, soldiers, captains and labourers all combined. Although they are called workers, they are really the masters, and control the destiny of the community, the kings and queens being mere puppets. They are busy all day long repairing or enlarging nests, going out for foraging food, placing the eggs in different chambers, according to requirements, and feeding the young ones. They also guard the nests. In an ant-colony, some of the workers are bigger than others in size, and are spoken of as soldiers. In times of danger, both the soldiers and workers offer an united front and fight gallantly against any invader of their hearth and home. Members of another colony are looked upon as intruders, and often the worker members of one community wage bitter war against those of another community; and the conquerors carry the spoil to their home.

As sons and daughters grow up they leave the paternal roof. A nuptial flight takes place. In bees, the daughters

leaving the home are accompanied by thousands of workers, this is known as *swarming*.

Ants—

In ants, the workers are wingless, the brides and grooms go out unaccompanied by their followers. After marriage in air, new homes are started.

The subsequent history of the ant and the bee is treated separately for obvious reasons.

The ant builds underground nests, or nests made of leaves, or of foreign matter. The honey-bee, unlike the ant, constructs nests called the hive or the comb made of wax secreted by the worker bees. The worker ant is wingless and differs from the worker bee in having a stalk joining the thorax with the abdomen forming thereby a narrow waist, which contains a single or double nodes or swellings.

Life-history of the ant—

After the nuptial flight the female ant descends from air and casts off her wings. She now looks like a worker, but the marks of lost wings still remain. She is readily distinguished from the wingless workers, as her abdomen is large, being distended with eggs. She seldom returns to the old colony. She is either sought out by worker ants, who build for her a new home and adopt her as the queen, or she finds for herself a new colony and becomes the queen of it. In the latter case she produces, first, a batch of eggs from which workers develop, and subsequently eggs which are capable of developing into males, females as well as into workers. The first batch of workers hatched, takes up the domestic duties, and the queen ceases to look after the children. Occasionally in a colony, when a queen is lost by a death or accident and no new queens are available to take her place, some of the workers lay eggs. But these

eggs are capable of developing into workers alone. As the workers are really undeveloped females, it is possible for them to become a mother when an emergency arises.

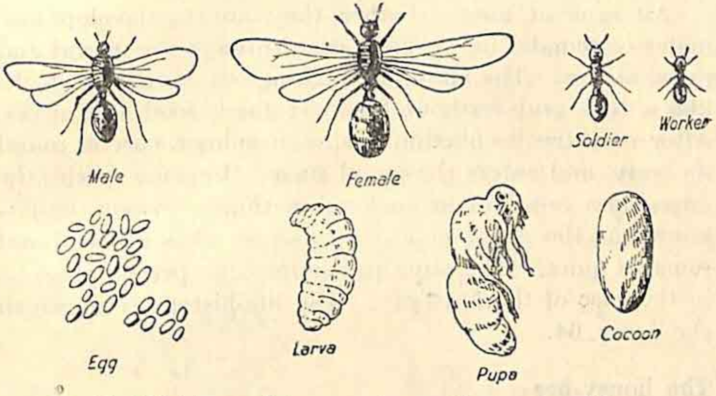

Fig. 64. Life-history of Ant—workers, male, female, soldier, egg, larva, pupa and cocoon

An egg of the earthworm, insect, fish, bird or snake, is a female reproductive cell. It is composed primarily of a single minute cell. But if the food material be stored in it, in a large quantity for the nourishment of the embryo to be formed, it looks bigger in size, and is often protected by an outer shell as in the bird. If a female reproductive cell is met by a male reproductive cell, the nuclei of the two unite to form the single nucleus of the egg ; and the egg thenceforth is known as the *fertilized egg*. The fertilized egg, like the seed of the plant, thus virtually is biparental in origin. The cell of the fertilized egg multiplies by division into a large number of cells, which ultimately form the body of the embryo that develops into a baby.

In case of social insects ordinarily the young is developed in a similar way from the fertilized egg. In rare instances, however, as in the case of the worker-ants, the eggs do not undergo any union with male reproductive cells, but

still they are capable of developing into young ones. Such eggs remain monoparental since their origin, and are known as the unfertilized or *parthenogenetic* eggs.

All eggs of ants, whether they are to develop into males or females or workers, pass through the larval and pupal stages. The larva on hatching out of the egg, looks like a tiny grub without legs. It takes food and grows. After reaching its maximum size, it spins a cocoon round its body, and enters the pupal stage. In some species the pupa does not remain enclosed within a cocoon, and is known as the *naked pupa*. The pupa takes no food and remains quiet. The pupa passes into the perfect stage as in the case of the butterfly. The life-history is shown in the figure, 64.

The honey-bee—

The hive or the comb of the honey-bee contains numerous hexagonal cells or chambers (Fig. 67), some of which are reserved as nurseries, and some as food stores. Each hive is the home of thousands of workers, a few hundreds of drones, and a single queen.

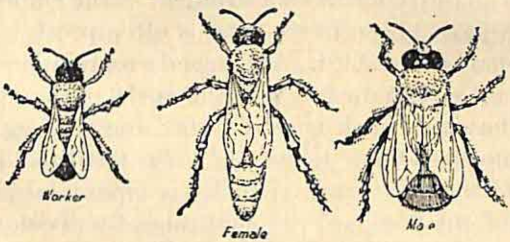

Fig. 65. Bee—worker, queen, drone

The worker bee, unlike the worker ant, is winged. It is smaller in size than the drone or the queen. The drone has a robust body, and is a noisy fellow. The queen is elegant looking and possesses a tapering abdomen (Fig. 65).

Insects possess three pairs of jaws which move from side to side. In worker bees, the first pair is situated by the sides of the mouth and is used for kneading wax. The other parts are drawn out in the form of blades, for cutting succulent vegetable tissues and protecting the delicate tongue which is hairy and drawn out in the form of a tube (Fig. 66). The worker bees suck sweet juices or nectars from flowers by means of the hairy tongue. The sweet juice thus collected from flowers changes within sacs of the digestive tube into honey. The worker bees on returning to the hive empty out the honey by regurgitating or vomiting, and store it in honey-chambers of the hive.

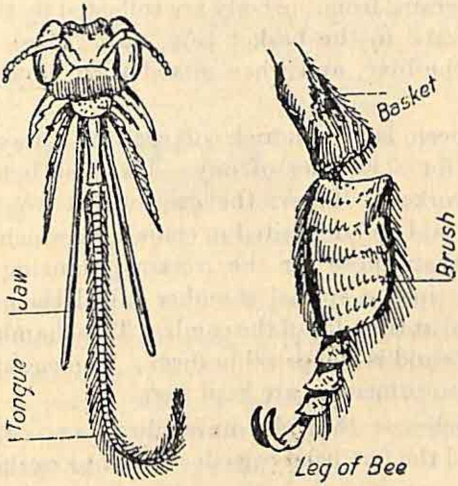

Fig. 66. Head of worker bee showing the hairy tongue and hind leg

During the period of construction of a hive, the worker bees absorb some of the honey, and collect themselves into a dense group and remain quiet. Flakes of wax come out from pores on the ventral surface of the abdomen. These are collected and form the material for construction of the

hive. Since the wax is produced at the expense of the honey, the *apiarist* or the bee-keeper uses the old hive for housing his domestic bees and recovers honey without destroying the hive, by resorting to scientific methods.

The body of the worker bees is hairy and therefore when the workers dive into flowers, the pollen grains of flowers gather round the body on account of the hairs on it. The worker bees help in the pollination of flowers by transferring pollen grains of one flower into the stigma of the other. A portion of the hind leg is grooved and forms a sort of a basket. The stiff hairs situated on the hind leg, behind the basket, are arranged so as to form little brushes, and the pollen grains from the body are collected by these brushes and packed in the basket (Fig. 66). These are transferred to the hive, and when mixed with honey form the bee-bread.

The queen lays hundreds of eggs in a day and this continues for a number of days. The first batch of eggs produce workers. Later, the eggs which would produce drones are laid and deposited in chambers, which are slightly larger than those for the worker-producing eggs. At about this time, a special chamber called the *queen cell* is constructed at the edge of the comb. This chamber is larger than others and is elongated in form. The eggs that would develop into princesses are kept here.

It is believed that the unfertilized eggs give rise to drones, and the fertilized eggs develop into workers as well as into queens, and that the mother queen is capable of controlling the birth of either type of eggs. The turning-up of females or workers, from the fertilized eggs, depend on subsequent feeding of the larvæ. The larvæ hatch out more or less within three days. All of them in the beginning are fed with a fluid coming out of the mouth of the nurses who are the workers. This food is very nourishing

and is called the *royal jelly*. Later, preferential treatment is made. Those who are to develop into queens, are fed throughout the larval life with the royal jelly ; while those to be made into workers are given bee-bread.

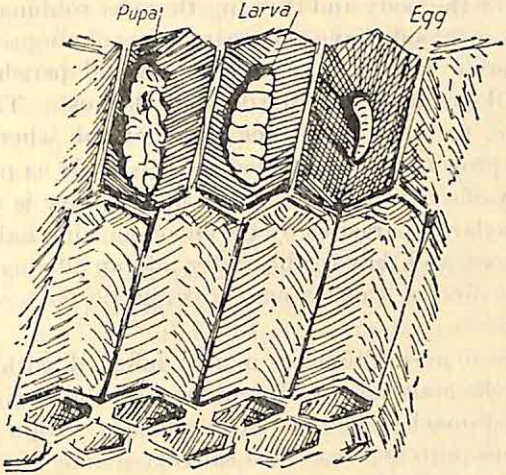

Fig. 67. Comb of the Honey-bee

All the larvæ as in the ant, pass into the pupal stage and emerge out either as males, females, or workers, according to the circumstances under which they have been reared. The queen generally takes 15 days, a worker 21 days and a drone 24 days, to complete the development from the egg to the perfect stage.

Mosquitoes—

The mosquitoes are the notorious transmitters of diseases like filaria, dengue and malaria which levy a heavy toll of death and devitalize millions of people every year.

Animals and organisms living within the body of another animals, are known as parasites ; and the persons harbour-

ing them play the part of an unwilling host by giving them food and shelter. The malarial fevers are caused by the tiny unicellular or protozoan animals living within the red blood corpuscles of man. These parasites dwelling in the interior of the body and thriving there by robbing nourishment from blood, have no means of communication with the exterior world, and, therefore, would perish like the helpless dependants with the death of the host. They have, therefore, to enter into some arrangement whereby they or their progeny may be transferred as early as possible to the body of a new host. Such an opportunity is presented to the malarial parasites by the blood-sucking habit of the mosquitoes, and they readily enter into an alliance with the latter for finding them a new host and do no harm to the carriers.

When a mosquito bites a man infected with malaria, it sucks the malarial parasites along with the victim's blood into its stomach. The parasites multiply within the body of the mosquito and pass into salivary glands of the latter. At the time of feeding on blood, the mosquito has the habit of spitting for preventing the coagulation of the human blood, and when it bites a healthy man, it injects along with the saliva the malarial parasites into the blood of this new host.

In this way the mosquito infects a number of persons with malarial parasites and spreads the disease. Similarly, a mosquito acts as a carrier of filaria which causes swelling of the leg called elephantiasis. The filaria is a small worm introduced into the blood and lymphatics of man. Theoretically, therefore, if the mosquito had no chance of ever coming in contact with any malaria-stricken or diseased person, it would be harmless except for its painful bites.

The male mosquitoes which are distinguishable from the females by having bushy antennæ, live upon plant

juice, and their mouth parts are such that they cannot puncture the tough skin and draw in blood from human beings. They are not harmful like the females.

The female mosquitoes alone are the dreadful carriers of diseases. They have a proboscis or a mouth-tube which contains inside delicate instruments for piercing and cutting even a tough skin and for sucking in blood. Their mouth parts thus differ from those of butterflies or bees which also live on liquid food, but not on blood.

Since the female mosquitoes bite the cattle also, it may be asked whether they can be induced to feed on the cattle in preference to human beings.

As the mosquitoes pass their early stages in water, and their larvæ, in spite of the aquatic habit depend on atmospheric air for respiration, a quicker method of destroying the mosquitoes is to employ kerosene oil which spreads as a thin film over water and thereby kills the larvæ by preventing them from rising to the surface of water for taking in air. The other methods would be to stock ponds with fish fries which feeds on mosquito larvæ or to destroy all breeding grounds of mosquitoes by filling in ditches and small tanks, and covering all water reservoirs by a fine net..

The *anopheles* mosquitoes carry the malarial parasites, and the *culex* filaria. They can be easily distinguished from each other or from other species of mosquitoes by their habits although the life-history is similar.

The anopheles sits on a wall or an object, with its body straight and inclined at an angle of 30°-90° to the surface on which it rests. The culex sits with its body humped nearly parallel with the surface on which it rests (Fig. 68).

Eggs are deposited on the surface of water, and they do not sink as they contain air-floats around them. The eggs of the anopheles float isolated with sides bulging out in the

middle. Those of the culex are set together as if in a raft (Fig. 68).

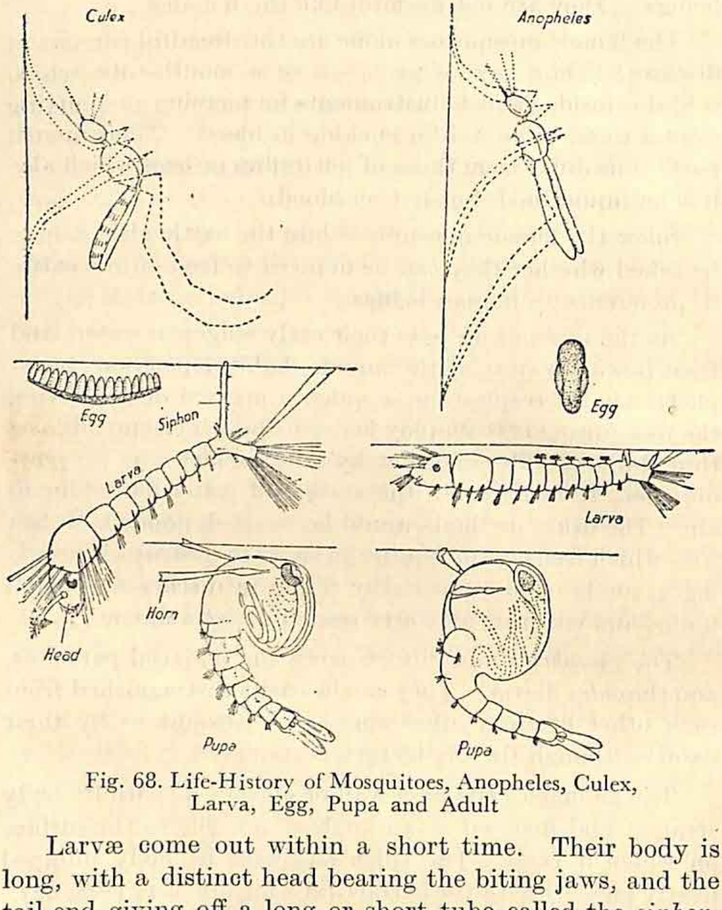

Fig. 68. Life-History of Mosquitoes, Anopheles, Culex, Larva, Egg, Pupa and Adult

Larvæ come out within a short time. Their body is long, with a distinct head bearing the biting jaws, and the tail-end giving off a long or short tube called the *siphon*, which bears at the tip the *spiracle* or the breathing pore. The larvæ are voracious eaters feeding on microscopic organisms present in water. They wriggle in water and

come to the surface for breathing atmospheric air by pushing out the siphon carrying the spiracle above the surface of water.

The larva of the anopheles rests keeping its body parallel with and just below the surface of water; its siphon is very short. It is distinguished by the presence of hairs which are arranged like the leaves of a palm tree. The larva of culex hangs down from the surface of water at an angle, and its siphon is very long.

Within a few days the mosquito larva passes into the pupal stage. In a pupa the head is swollen and bent on the body so that it looks like a comma. The pupa floats in water. Behind the head, there are two horn-like projecting tubes on each side. The spiracle is borne on each such horn and the pupa takes in and respires atmospheric air. The length of the horns in the two species is different (Fig. 68), in culex it being longer. The pupa does not take any food. It is, however, an active creature paddling down in water by flaps at the end of the tail and rising up by buoyancy. Great changes now take place within the body of the pupa. Within a week or so the shape of the perfect form can be seen enclosed within the skin of the pupa.

Then the pupal skin splits, the winged insect comes out, and stands on the floating pupal case for about a minute and then takes its flight in air.

The Spider—

The spider is characterized by having four pairs of walking legs. It is readily distinguished from other arthropods not having antennæ on the head and is placed under a distinct class called *Arachnida* (Fig. 69). The spider differs from an insect in having its head fused with its thorax forming what is called a *cephalothorax*. The abdomen is separated from the cephalothorax by a narrow constriction

forming a sort of a narrow waist. Unlike in insects or other arthropods, the abdomen of the spider does not show any external sign of segmentation.

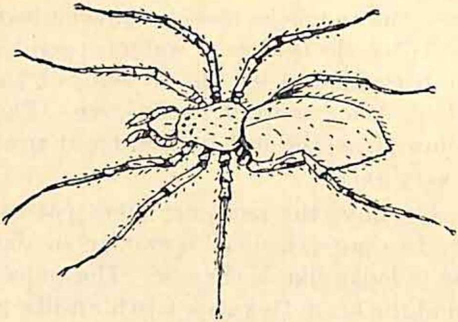

Fig. 69. Spider

The front of head is studded with 3 or 4 pairs of rounded and glistening eyes which are separate from one another and resemble the simple eyes of insects.

The mouth is a narrow slit not clearly visible from the outside. It is flanked by a pair of very short hook-shaped jaws which pierce and inject a venom into the body of its victim and kills it ; and the juice of its prey is sucked in by the mouth. It does not live on solid food.

In the anatomy of its body the scorpion resembles a true spider except for the fact that its body is long and bears a poison-sting at the tail-end. The *pedipalp*, which is long and provided with a pincer-like claw in the scorpion for seizing its prey, is short and is without the claw in the true spider. The pedipalp of the spider projects in front of the head and should not be confused with an antenna which rises from the top of the head.

The abdomen of the spider contains on the ventral surface a number of eminences called *spinnerets*. The secretions of the spinning glands which are located inside the

abdomen, come out through the spinnerets and when dry form fine threads or cobwebs.

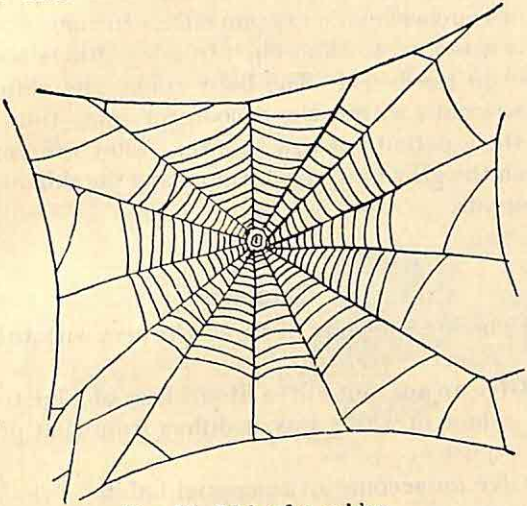

Fig. 70. Web of a spider

The drawing of threads for making its web, is often manipulated by its hind legs. Different types of web are made by different species. An orb web is constructed by attaching one end of the thread to some fixed object and drawing the other end across a space selected for laying the snare. A few threads are laid first in radiating lines and they form the foundation lines. On these lines other threads sticky in nature are spirally laid so as to form a complete web (Fig. 70). The spider stands at the centre of the web, or remains in hiding, holding one of the threads by its leg. As soon as an insect gets entangled in the sticky threads of the web, the spider knows it by the vibration of the threads. It then rushes out, gives a bite and spins thread around the struggling victim. It then proceeds to suck its body dry.

The male spider is smaller than the female and is often put to death by the wife. The female deposits eggs in a cocoon or egg-case made of spun silk. In some species the cocoon is attached to the web. In a few others the cocoon is carried in the body. The baby spiders hatching out of the eggs remain within the cocoon for some time and resemble their parents except in size. They are very small and reach the grown-up size by moulting the skin at periodical intervals.

Questions

1. Compare the body of an earthworm with that of an insect.
2. Give an account of the life-history of a butterfly and show in which way it differs from that of a mosquito.
3. Give an account of the social habits of the ant and the bee.
4. How do bees store honey in their combs ?
5. What is the food of the spider ?

CHAPTER XIII
THE FISH

Our edible fishes like "Rohu", "Catla", "Hilsha", "Bhetki", have an internal skeleton composed of bones. They are, therefore, known as *bony fishes*. Others like the "shark" and the "dogfish" have the skeleton made of cartilage. Hence these are called *cartilaginous* fishes. The central skeleton in both cases consists of a vertebral column or backbone, composed of pieces called the *vertebræ* and a skull containing the brain (Fig. 71). The digestive tube

or the alimentary canal runs through the body cavity from the mouth to the anus and is distinguishable into the *pharynx*, *œsophagus*, *stomach* and *intestine*. The mouth leads into the pharynx. The pharynx is perforated on each side by a number of slits which open into the gill-chambers.

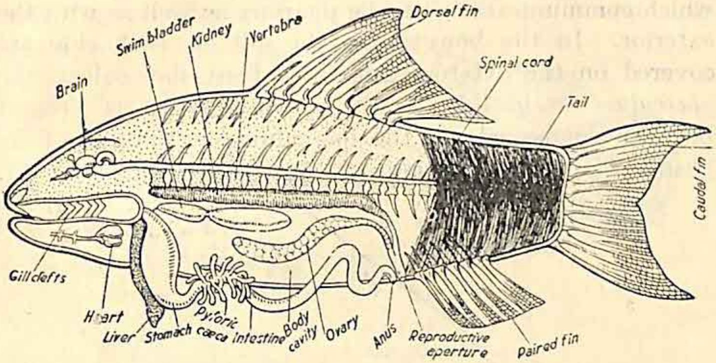

Fig. 71. Anatomy of the Fish

The stomach is more or less 'U' shaped. The intestine is coiled and gives off in certain fishes blind tubes called *cæca* (Fig. 71). Teeth may be present or absent in jaws. They facilitate the seizing of food. Teeth may also occur within the pharynx. A short tongue is present. As in other vertebrates the body cavity contains liver, gall-bladder, and other organs. The central nervous system composed of the brain and the spinal cord, lies on the dorsal side of the body, and is placed above the gut and the vertebral column (Fig. 71) ; while the heart as in other vertebrate animals lies on the ventral side.

The fishes are truly aquatic vertebrates and differ from a number of other vertebrates like the "whale" and the "porpoise" which also live in water, but which have to come to the surface of water to breathe atmospheric air.

The fishes carry on respiration while under water. This they can do as they possess gill which take up oxygen from the water containing a certain amount of air dissolved in it. Gills are comb-like frills, red in colour and placed on each side of the head in a chamber called the gill-chamber which communicates with the pharynx as well as with the exterior. In the bony fishes the gill on each side are covered on the external side by a bony flap called the *operculum* or the lid. A slit or exit aperture is present between the free edge of the operculum and the side of the head. The gills are shown exposed, in the figure 72.

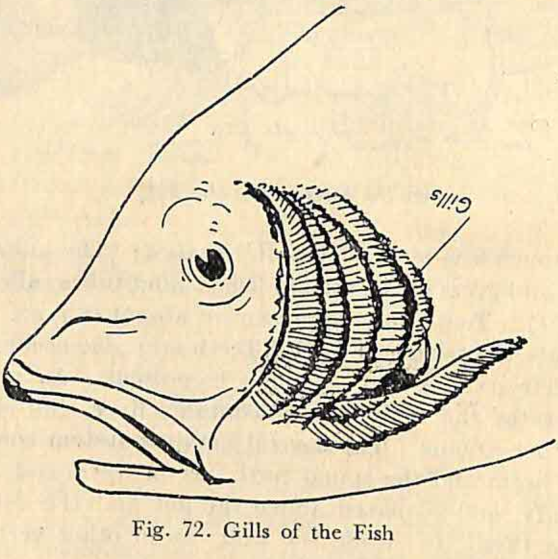

Fig. 72. Gills of the Fish

Water taken in by mouth, passes from the pharynx to the gills and thence through the exit apertures to the exterior. The gills are richly provided with capillaries of fine blood-vessels. As the blood driven by the heart, passes over the gills, it becomes purified or oxygenated, and is sent out

through the blood-vessels to different tissues. Blood is brought back by a set of vessels called veins from the tissues into the heart.

While the fishes in general are only capable of breathing in water by means of gills, there are several fishes which can respire while out of water. "Kai", "Magur" and

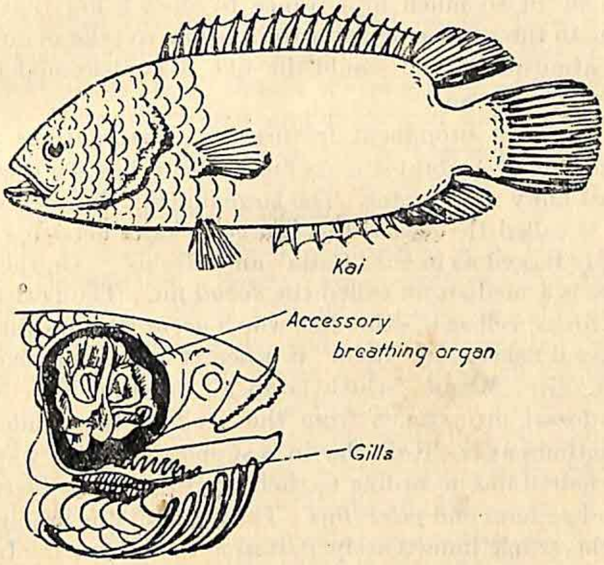

Fig. 73. "Kai" and its head showing air-breathing organ

several other fishes live in shallow pools which dry up in summer seasons. They have then to depend on atmospheric oxygen for respiration. They meet this want and take in oxygen from the atmospheric air by means of an accessory breathing organ which in "Kai" is composed of scroll-like structures placed behind the head (Fig. 73). It is different from the lung although it acts like the latter, in taking in oxygen from the atmospheric air. The fishes provided with the accessory respiratory organ thus carry

on double method of respiration, in the sense that they breathe water as well as air. On account of this adaptability such fishes can live out of water for a long time ; and the "Kai" is known to walk long distances on land and is believed to climb trees. The latter habit has earned for it the name "climbing perch". The air-breathing habit has become of so much importance to such fishes that they come to the surface of water from below to take in air from the atmosphere and would die like a land animal if not allowed to do so.

The most prominent feature that distinguishes a fish from other vertebrates is its fins. The fishes are therefore called finny vertebrates. The large fin (Fig. 71) at the tail-end is called the *caudal* fin. In good swimmers this fin is deeply forked as in our "Catla" and "Rohu". On the back there is a median fin called the *dorsal* fin. The position of this fin as well as of other fins which occur in pairs varies in different fishes. In "Rohu" it is nearly in the middle of the back. In "Magur" which is an air-breather like "Kai", the dorsal fin extends from the neck to the caudal fin. Sometimes as in "Kai" the fin is supported by bony spines. The paired fins according to their positions in the body, are called *pectoral* and *pelvic* fins. The pectoral fins are present on the trunk immediately posterior to the head. In our "Singhi" fish, a spine is present in this fin. The spine can inflict a painful wound. The paired fins help the fish in slowly paddling through water, and in maintaining the vertical balance when it is resting.

In most of our edible fishes a long bladder filled with gas is found inside the body. It is called the swim-bladder as it was believed that it enabled the fish by changing the pressure of the gas to go up and down in water.

Most fishes which are good swimmers like "Rohu", "Catla" and "Hilsha", have a body admirably suited for

cutting swiftly through water. It is spindle-shaped and compressed from side to side. The body is divisible into the head, trunk, and tail regions. The anal aperture marks the boundary limit between the trunk and the tail. The head is broad with a large mouth-opening. In some fishes called "cat-fishes" (Magur, Singhi, Tangra, and Mangofish) there are long thread-like structures on the sides of the mouth called *barbels*. Double nostrils occur. These are not for breathing but for smelling objects. The sense of smell is so keen in a shark that it can easily follow its prey by scent. Eyes are round and large and have no eyelids. The curvature of the lens in the eye does not change as in man and the mode of vision is different from that of a man. There is no sign of an external ear.

The body of most fishes is covered with large scales. Our "Magur" and "Singhi" are exceptions. The external surface of the body is covered by a slippery skin or epidermis which invests the scales where present. The epidermis contains glands which secrete a mucous substance that makes the fish a "slippery animal".

Running along each side of the trunk is a line called the *lateral* line. Along this line are sensory cells by means of which the fish can detect vibrations in water.

Fishes inhabit ponds, lakes, rivers and the sea. "Catla" and "Rohu" like the English Carp, are fresh-water fishes, and they are stocked in large tanks. They do not breed in confined waters. In spawning time they ascend rivers and go near the source of rivers. Eggs are produced in ovaries and laid in millions. Young ones or fries live on microscopic organisms. As they grow a change in feeding habit takes place. Mature "Rohu" is said to be omnivorous. Both animal and vegetable matters serve as its food. Mature "Catla" feeds on aquatic weeds like the algæ. Some fishes like the "Chital", prey on other fishes. There-

fore in stocking tanks with edible fishes they should be excluded. Certain fishes, like the "Shole", show care for their young ones.

The "Kai" spawns in April and May. The brown ova of the size of mustard seeds are laid on submerged weeds. Young fishes hatch out of these eggs.

Questions

1. Enumerate the characteristic features of a fish.
2. How does a fish respire and why does it not get drowned in water ?
3. Name the common edible fishes and state what you know about their habits.

CHAPTER XIV
THE FROG

The frog whose early life is spent entirely in water can live on land and under water. The body is distinguishable into a head and a trunk, and there is no neck joining the two. A pair of nostrils on the snout leads air into the mouth or buccal cavity. As the mouth is shut, the throat which forms the floor of the buccal cavity, is moved up and down. When it is raised the nostrils are closed by valves and air is forced into the lungs. It cannot inhale air if the mouth be kept open, and thus differs from a mammal in which the abdominal wall moves during breathing.

The eyes are prominent and are provided with eyelids. There is a circular patch of stretched skin on either side of the head. This represents the *tympanic* membrane or the drum of the ear. There is no projecting external ear. But

a frog is neither deaf nor dumb. The male has a vocal sac which becomes inflated as the frog croaks for its mate. The sac acts as a resonator and intensifies the sound given out by the voice-box.

The skin is smooth and is not covered by scales or hairs. The toad resembles the frog but its skin is warty.

The skin supplements the action of the lungs by absorbing oxygen from air. It also absorbs moisture. The frog, therefore, has no necessity to drink water. But water may also evaporate through its skin. In dry weather, therefore, the animal seeks damp holes. Legs show adaptability to both terrestrial and aquatic modes of life. The hind legs are longer than the forelegs and enable the animal to take long leaps. The fingers of the hind feet are webbed and help in swimming.

The mouth is large and opens wide. The tongue is long and fastened in front. By thrusting out the tongue which is sticky, the moving insects are caught and drawn into the mouth. The frog snaps at any moving object even it be a hook. Large objects are helped into the mouth by the forefeet. It feeds on the earthworm and insects, but ordinarily it will not take dead animals or objects which are not moving.

The frog and the toad migrate to water for spawning. The eggs are laid in water ; and in common frogs and toads they are not taken care of by the parents. In the frog, each egg is enveloped with a gelatinous covering which absorbs water and swells up (Fig. 74). In the toad the eggs form a string and remain closed within a long gelatinous tube attached to submerged weeds. The life-history of the frog and the toad is similar. The egg develops into a small embryo (Fig. 74). The embryo comes out of the gelatinous capsule of the egg and is now called a larva. The freshly hatched larva is blind and without a mouth. It is not very

active at this time but can swim a little. It generally adheres to aquatic plants. It respires by long tufts of gills which hang out from the sides of the head. They are visible from outside, and are called external gills. Later the mouth is formed and is provided with a pair of black horny jaws. The alimentary canal is enlarged and the intestine becomes coiled. The larva is known as the *tadpole.*

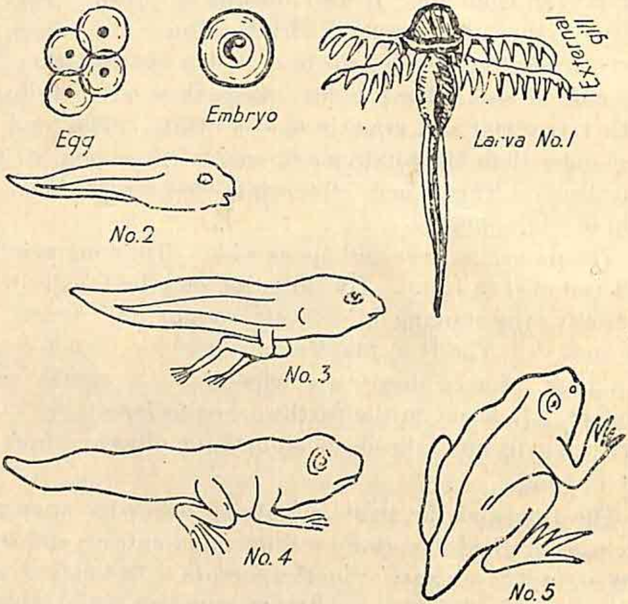

Fig. 74. Life-history of the Frog—egg, embryo, tadpoles

The tadpole feeds on water weeds but also relishes animal food. Subsequently the tufts of external gills begin to shrivel up and are ultimately lost; and the internal gills like those of fishes make their appearance. Meanwhile an operculum or lid grows up and covers the gills.

The tadpole is now practically like a fish (Fig. 74, No. 2). It is limbless and is without any external gills. It swims by the tail fin, and respires by drawing in a current of water into its mouth and sending it out like a fish over the internal gills. After a month or so, the transitory stage follows. Lungs commence to develop and the internal gills begin disintergrating. The tadpole now practically rises to the surface of water to take in a gulp of air. The fore and hind limbs grow out. At first, the forelimbs remain concealed under the operculum, and the hind limbs or legs alone are visible (Fig. 74, No. 3). The tadpole appears, therefore, as a two-legged creature with a long tail. Gradually both pairs of limbs become visible. As the legs increase in length, the tail diminishes. The tadpole is now at the close of its aquatic life, and a great change comes over its body. It stops eating. The old skin is cast off ; the mouth becomes like that of the true frog, and respiration is done by lungs. It now jumps on to land and looks like a miniature frog with a tail (No. 4). Then gradually the tail dwindles away and the animal is known as the *juvenile frog* (No. 5). The little frog in a few years reaches maturity.

Questions

1. Which food does the frog like best ?
2. How would you distinguish a fish from a tadpole ?
3. Give an account of the life-history of the frog or toad.

CHAPTER XV

HUMAN PHYSIOLOGY

The General organization of the human body—

The human body can be distinguished into a *head* and a *trunk*. The neck joins the head with the trunk. The trunk carries the upper and the lower limbs, and is subdivisible into the chest or the *thorax*, and the belly or the *abdomen*. The thorax has in it a large cavity which contains the two *lungs* and the *heart* (Fig. 75). The gullet or the *œsophagus* passes through this cavity. Inside the abdomen likewise, there is a cavity which is occupied by the *liver*, *spleen*, *stomach*, *intestine* and the *kidneys* (Fig. 75). The two cavities are separated by a partition called the *diaphragm* (Fig. 75). This diaphragm is arched and allows the gullet to pass through it. When the diaphragm is flattened down by muscular action, the thoracic cavity is enlarged. It is also enlarged when muscular action raises the ribs. This alteration of the thoracic cavity has great bearing on the

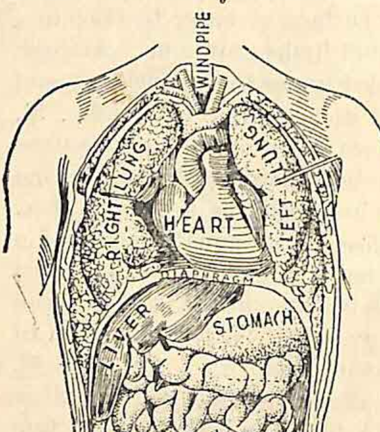

Fig. 75. Body cavity exposed showing thoracic and abdominal cavities, position of diaphragm, heart, intestines, etc.

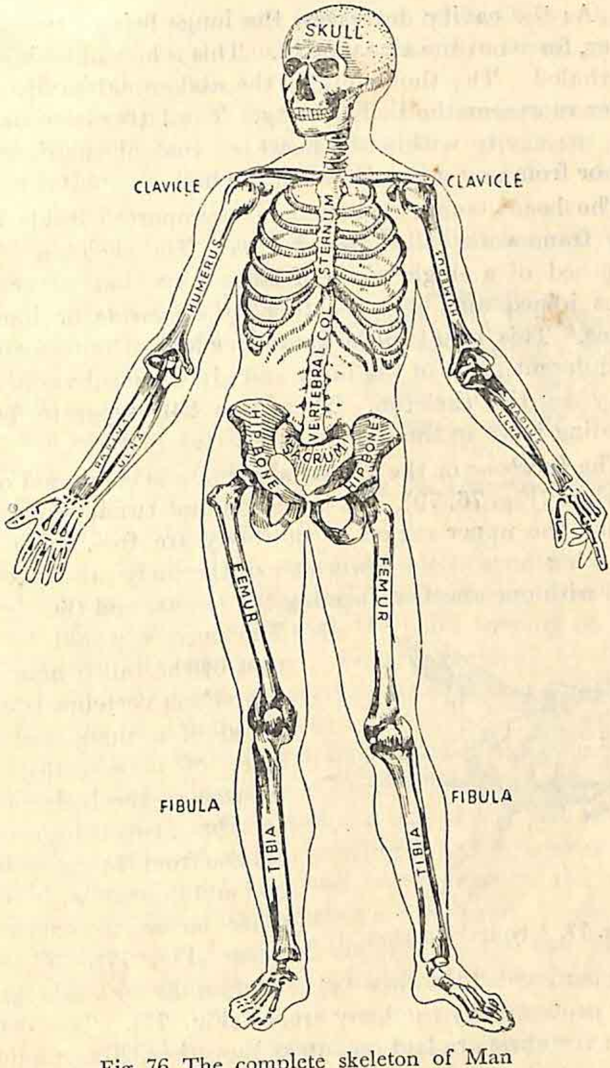

Fig. 76. The complete skeleton of Man

breathing process. As the cavity increases, the lungs contained within it, expand and take in a deep draught of

air. As the cavity decreases, the lungs being pressed together, force out the air taken in. This is how air is inhaled or exhaled. The thoracic and the abdominal cavities together represent the body cavity. The latter is separated from the cavity within the heart, or that of the digestive tube or from any other spaces in the body.

The head, trunk, and limbs are supported inside by a bony framework called the *skeleton*. The skeleton is not composed of a single piece of large bone, but of several pieces joined and held together by *ligaments* or binding tissues. This results in a great freedom of movement of the different parts of the body and gives considerable flexibility to the skeleton. There are 249 separate bones including teeth in the human body.

The *backbone* or the vertebral column is composed of 33 vertebræ (Fig. 76, 79). Of these the first twenty-four supporting the upper region of the body are free, while the remaining ones at the lower end of the body are united or fused with one another, forming the *sacrum* and the *coccyx*.

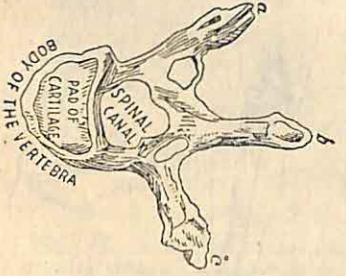

Fig. 77. A typical Vertebra

The coccyx would be the root of the tail if man had one. Each vertebra is composed of a thick and flat piece of bone called the *centrum* or the body of the vertebra ; two bony processes rise from it ; these curve up and meet with each other so as to enclose a space (Fig. 77). The big nerve cord called the *spinal cord* courses through this space, being protected by the bony arches (Fig. 77). The centre of the vertebræ are laid one upon the other, like a pile of coins and the surface of contact between two successive

vertebræ is coated with a soft pad made of cartilage. This cartilaginous pad like a cushion absorbs any shock given to the vertebral column.

The neck is supported inside by the first seven vertebræ. Of these the first and the second are very peculiar. The head or rather the skull, rests on the first vertebra which is called the *atlas* after the name of the giant who carried the earth. There are two bony knobs called the *occipital condyles* at the base of the skull. These two condyles fit into two sockets on the first vertebra (Fig. 78, *a*, *b*). This ball and socket joint allows the head to move as in nodding. Again, the first vertebra is hollow in the centre, forming a ring. Into this ring fits a peglike process of the second vertebra, *the axis*, thereby making a pivot joint ; the head can thus turn sideways, the atlas together with the skull turning on the pivot. These movements are, however, limited by ligaments which bind these bony parts so as to prevent complete twisting of the head and the neck.

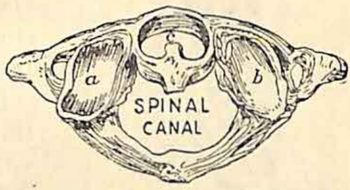

Fig. 78. Top view of Atlas Vertebra

The vertebræ of the thorax follow those of the neck and are 12 in number. They are connected on the sides with the ribs. The other end of each rib except the last two is connected by means of cartilages with the breast-bone or the *sternum*. The thoracic vertebræ together with the ribs and the sternum thus form a sort of a bony cage.

The remaining vertebræ of the trunk form the backbone of the abdominal region, and include the sacrum and the coccyx.

The bones of the head form the skull. The skull contains a large cavity called the *brain-box*. This brain-box

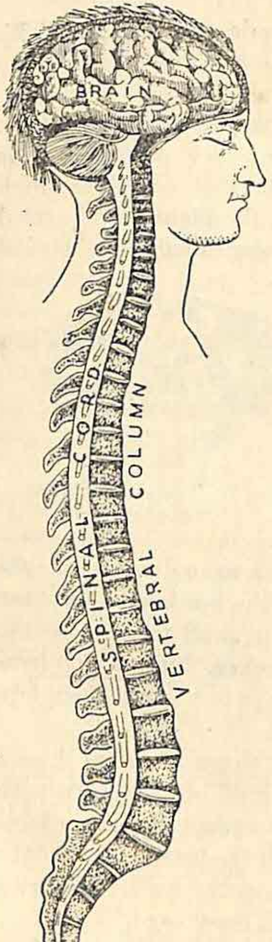

Fig. 79. Vertebral column showing Spinal Cord and Skull enclosing Brain

is shut off from the cavities of mouth, ear, nose, as well as from outside. The brain is lodged within the brain-box, which is composed of several, more or less, flat pieces of bones that are fused with one another. From the brain nerves pass out to the eyes, the ears and the nose, through small openings in the walls of the box. There is a large aperture called the *foramen magnum* through which the spinal cord passes out of the brain-box (Fig. 79).

The upper jaw is fused with the skull, while the lower jaw is articulated with the skull by a joint and is capable of up and down movements. The teeth are implanted into the sockets of the jaws and are differentiated into cutting, flesh cutting and grinding teeth.

The upper limb is composed of a long bone in the region of the upper arm, two long bones in the forearm, and two rows of small wrist bones. Bones also support the hand and fingers. The long bones are hollow and contain marrow. The bone of the upper arm is called the *humerus*. The upper end of the humerus gives off a bony ball which fits

into a shallow cavity of the shoulder-blade, called the *scapula*. The ball and socket joint permits rotatory motion of the forearm. The collar bone or *clavicle* keeps the shoulder girdle in position.

The bones in the forearm are known as *radius* and *ulna*. The ulna at its upper extremity is bent in the form of a hook which fits into a groove at the lower extremity of the humerus. Such a joint prevents the forearm from moving back when the arm is stretched out.

The construction of the lower limb is similar to the upper one. The long thigh bone called the *femur*, has a large rounded process which fits into a deep socket on the side of the hip-girdle. The ball and socket joint permits forward and backward movement of the thigh. The hip-girdle looks like a bony basin, and is connected in the sacral region with the vertebral column.

The lower end of the femur rests on the *tibia* or the shinbone. The fibula is slenderer than the tibia and runs parallel to it. Where two long bones join, the junction is lubricated by a fluid called *synovia*. The knee-joint is protected from knocks by the knee-cap called the *patella*. The foot is supported by a series of short bones which have different names. It is worth noting that the great toe in relation to the foot, is differently placed from the thumb in relation to the hand. The hand can grasp an object, the thumb being movable and opposable to the hand. The great toe has no such movement.

The foot is slightly arched in the middle, the heel and the ball of the foot resting on the ground. The middle portion being raised, the foot acts as a spring, when the weight of the body falls on it.

The erect posture of the body is a characteristic feature of man. If an attempt is made to make the prepared

skeleton stand on its own leg, it will not succeed because the vertical position is maintained not by the bones but by muscles passing along the different parts of the body. The movements of the different joints are likewise effected by means of muscles. Thus the *biceps muscle* connecting the scapula with the radius, by contraction raises the arm, which in turn becomes extended by the *triceps muscle* (Fig. 80). The muscles are controlled by nerves. The nerves may be compared to conducting wires through which messages are sent to, and received from the brain and the spinal cord. The muscles act in obedience to the impulse received through the nerves.

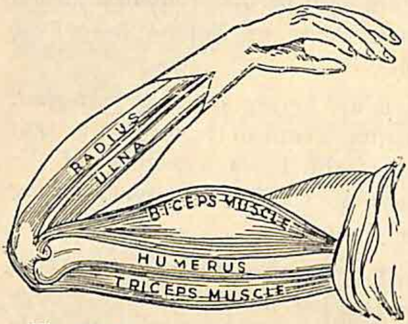

Fig. 80. Biceps and Triceps muscles

Questions

1. Describe the surface anatomy of a human body.
2. How do muscles act in moving our limbs ?
3. What is the function of the skeleton system ?

CHAPTER XVI
THE NERVOUS SYSTEM

The nervous system consists of the brain, spinal cord and nerves.

The brain is a soft mass composed of nerve cells and their fibres. It is the chief centre for regulating the work of the different systems present in the human body. It is a delicate but important organ. It is, therefore, kept well protected within a bony-case in the head called the brain-box (Fig. 79) and is covered by thin coatings called *meninges*.

The brain is divisible into several portions. The largest portion is known as the *cerebrum*. It nearly fills the whole of the brain-box. It is divisible by a deep groove or fissure into two halves called the *cerebral hemispheres*. At the bottom of the fissure, the two hemispheres are connected with each other by a flat band of nervous tissue. The upper surface of the two hemispheres is thrown into deep wrinkles, or convolutions, and is divisible into smaller areas or lobes which are concerned with hearing, vision, perception, and thinking. The two hemispheres, therefore, can be described as the seat of understanding and memory.

Behind the cerebral hemispheres lies the next important portion called the *cerebellum*. It serves to maintain the equilibrium of the body by co-ordinating the activities of muscles and other organs.

The cerebellum is anteriorly connected with the cerebral hemispheres, and posteriorly arises from the piece called the *medulla*. The medulla continues behind as the spinal cord. The medulla is the centre for controlling respiration and circulation of blood.

The brain, if it is cut into slices, is found to be divisible into an outer layer called the *grey matter*, and an inner

core called the *white matter*. The grey matter is full of nerve cells and is the real seat of mental processes. The white matter consists of fibres that put the cells of the grey matter into communication with different parts of the brain.

The brain is not a solid lump of nervous tissue, but contains small spaces which are continuous with one another and with the cavity running through the spinal cord. The spaces are filled with fluid called the *cerebro-spinal* fluid.

From the brain are given off twelve pairs of nerves which come out through small holes in the brain-box to the eye, ear, tongue, jaws, face and other organs.

The spinal cord is a long nerve tube which runs along the trunk coursing through the bony arches of the vertebræ (Fig. 79). It gives off thirty one pairs of nerves which are distributed over various parts of the body.

The nerves carry messages from the sensitive skin and other organs to the spinal cord. The spinal cord may act independently or may send the messages or impulses received to the brain. The nerves transmit the impulses to the brain or the spinal cord and also transmit directions from them to the skin or other organs. The impulses or orders from the brain are carried by relays to the muscles, and the muscles act according to the directions received from the centre.

The brain acts as the Head telegraphic office, and the spinal cord as the local telegraphic office receiving and sending out messages. The nerves act as telegraphic wires.

When we put our foot on a burning piece of coal, we withdraw our foot without doing any thinking. In this case the message sent by skin goes through the nerves to the spinal cord, and the spinal cord sends the orders through nerves to the muscles of the foot. The muscles contract and the foot is withdrawn. This is called a *reflex action*, and the head office or brain is not responsible for this action.

If we want to keep our foot on the coal the brain must be informed through the spinal cord.

The nerves arising from the brain and the spinal cord, break into finer twigs, and end on all parts of the body. Therefore, each part of the body—the heart, lung, muscle and skin—is under the control of the brain and the spinal cord.

Sensory organs—

Eyes, ears and skin are important sensory organs.

The eye is a spherical ball built like a photographic camera. A lens projects the images of objects on a sensitive screen situated behind the eyeball. The screen is called the *retina* and is supplied by a nerve from the brain. The impressions on the screen are interpreted by the brain.

The ear trumpet leads into a small passage. The passage ends at the ear-drum. The ear-drum is set into vibration by the sound waves. Far within it, there are devices of little chains of bones, and a coiled tube for transmitting the auditory sensations to the brain. The internal ear also possesses three semi-circular canals by means of which the direction in which one moves, is perceived. One reels if boxed in the ears because of the disturbance in the semi-circular canals.

The skin gives us the sense of touch because it is supplied with fine nerve twigs. It acts not only as a sensory organ but is also protective in function. It contains hairs and sweat glands, and perspiration flows out of it. Perspiration keeps the body cool.

Questions

1. What happens should one be knocked on the head ?
2. Describe the different parts of the brain mentioning their functions.
3. Explain what you understood by *reflex* action.

CHAPTER XVII
RESPIRATION

We are breathing continuously by day and by night. As we breathe in, air passes through our nostrils to a wind pipe and thence to the lungs which are like two bags (Fig. 75). The wind pipe starts from the mouth at the back of the throat, and running within the chest, divides into two branches called the *bronchus*. The branches divide and sub-divide into fine air-channels which open into tiny air-sacs permeating the lungs.

Blood streaming through the lung absorbs oxygen from the air which has passed into these tiny sacs and gives off carbon dioxide which had been formed in the tissues of the body.

The red blood corpuscles contain a peculiar substance called *hæmoglobin* which readily combines with large volumes of oxygen. The red blood corpuscles carry away the oxygen from the lungs to the tissues on the body.

The forcing of air into the lungs is influenced by the chest cavity. The chest cavity has not only movable walls formed of ribs and breast-bone but has a movable floor which is formed by the diaphragm (Fig. 75).

The chest expands as we inhale air and is relaxed as we exhale air. The exhaled air is rich in carbon dioxide and poor in oxygen. The air we inhale should be fresh and rich in oxygen.

Questions

1. Describe the changes in our chest as we inhale and exhale air.
2. Why do we pant for breath after a hard physical exercise ?
3. What is respiration ?

CHAPTER XVIII

FOOD

Rice is rich in starchy matter. Starch is a carbohydrate. The tomatoes and oranges contain vitamins. Ghee is rich in fat. Meat and egg are principal protein foods. Thus we find that some food is rich in one substance, some in another. A human being requires carbohydrates for production of energy, and also proteins and vitamins for the building up of the body. He cannot live without water. What he wants is, therefore, a balanced diet containing all the essential ingredients. The Nutrition Research Board of India has worked out a balanced vegetarian diet, the composition of which is roughly as follows : rice 10 ozs., millet 5 ozs., milk 8 ozs., pulses ('arhar' or gram) 3 ozs., non-leafy vegetables (brinjal, lady's finger, gourd, etc.) 6 ozs., green leafy vegetables 4 ozs., fats and oils 2 ozs., fruits (mangoes, plantains, etc.), 2 ozs. This diet contains carbohydrate, protein, fat, calcium, phosphorus, iron and vitamins, and is at the same time inexpensive. Fish may with advantage be added to it, as it contains nearly 20% protein as well

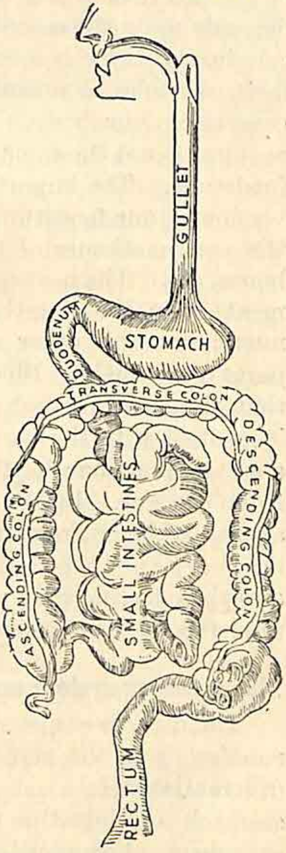

Fig. 81. The centre Alimentary Canal unravelled

as valuable calcium, phosphorus and iron salts. It should be observed that milk contains all the essential elements for the nutrition of the body and is the best type of food we have.

In prescribing a diet we have to remember that the body is composed of living cells, and the activity of our body depends upon the co-ordinated action of these cells. Each cell in the body is working and should have food. The food, we take, is meant for sustenance of tissues or cells composing our body. However, the food that a tissue requires is not the same as we take, but is derived from our foodstuffs. The important question is, therefore, the conversion of our foodstuffs into such products as can nourish the various tissues of the body, such as nerves, muscles, bones, etc. The next question is how to send out the nutriments from the digestive tube (which has no direct communication with other organs like the skin, brain), to other parts of the body. Blood is the only thing inside the body that circulates through all the parts of the body, and comes in contact with the various living tissues. It is, therefore, a suitable medium for the distribution of the food absorbed from the gut. Before the transportation of food by the agency of blood from the gut to a tissue can be done it is necessary that the food should be so changed as it can be absorbed by the living tissues of the body, and that it is rendered fit for transportation by blood.

The digestive system and digestion—

The digestive tube or the alimentary canal is a long tube running from the mouth and ending on the anus, and is differentiated into several parts such as the œsophagus, stomach and intestine (Fig. 81). According to the nature and chemical composition of the foodstuffs, they are transformed in different parts of the gut. Thus carbohydrate

is rendered into soluble sugar solution in the mouth cavity, proteins are converted into soluble products such as *peptones* in the stomach and the small intestine ; fat, protein, starch are made into an assimilable form in the small intestine and so on. The foodstuffs thus after being converted into proper nutrient substances are absorbed by the walls of the small intestine, and are distributed from there to the tissues through the agency of blood. The substances or reagents necessary for converting the foodstuffs in the different parts of the gut into required soluble forms are manufactured or elaborated by special glands. These glands are composed of a group of living cells set apart for the purpose, and they secrete the necessary reagents. The gland cells may be present in the walls of the gut or far away from the gut. In such a case a passage called the duct of the gland joins the gland with the gut. Liver and pancreas belong to this type. The secretions of the glands flow through the duct into the cavity or lumen of the digestive tube and operate there on the foodstuffs. Different glands produce different substances which act on different components of the foodstuffs. Thus *hydrochloric* acid and pepsin, are produced by the glands of the stomach and act on protein ; *ptyalin* is produced by the salivary glands and acts on starch.

Ptyalin, pepsin and such reagents are known as *enzyme.* The enzyme is notably different in action from ordinary chemical compounds such as hydrochloric acid. The latter if it acts on chalk will liberate carbon dioxide but itself will be used up in the process. The enzyme will act upon a substance, but it will not be converted or used up in the process. The result is that a small portion of enzyme can act upon a large amount of the substance. The enzyme has also some other peculiarities. Some enzyme act when the medium is acid, some act in alkaline medium. Thus pepsin

which is an enzyme produced by gland cells of the stomach will act in the stomach as it is acidified by hydrochloric acid and breaks up protein into peptone ; while the enzyme given out by the pancreas acts in an alkaline medium.

The digestive tube running through the body cavity possesses a thick wall which contains among other tissues, a type of muscles called the *involuntary muscles.* They are so called because they act involuntarily, that is to say, their action does not, like our biceps or triceps muscles, depend on our will. Waves of contraction pass along the tube rhythmically from before backward, driving the contents of the gut from one part to the next. This rhythmic motion of the gut is called *peristalsis.*

The process of digestion is as follows :

The food eaten is first chewed in the mouth cavity. The food is thus broken into shreds which become mixed up with the salivary secretion. The watering of mouth at sight of tempting food is due to flow of saliva or secretions from the salivary glands. There are three pairs of salivary glands. A pair called the *parotid glands* is situated under each ear. The inflammation of these glands is seen in mumps.

The saliva contains a substance called *mucin* which renders food slimy enough to be swallowed with ease. In addition to this, it contains an enzyme called ptyalin. Ptyalin acts on the starch of the foodstuff and turns it into sugar solution. This is the reason why fried rice tastes sweet after mastication ; but ptyalin cannot act upon other ingredients such as protein, and fat. The food after treatment in the mouth cavity, passes into the gullet or the œsophagus.

During its passage, it is prevented from deflecting into the wind pipe or *trachea*, by a cartilaginous flap called the *epiglottis* placed behind the root of the tongue. The trachea situated in front of it, and parallel to the œsophagus,

communicates with the mouth cavity, for drawing in the respiratory air ; but for the epiglottis there will be always a danger of the food going the wrong way.

The œsophagus is a fairly wide tube, 9 inches in length. It descends vertically down through the neck and the thoracic cavity, and opens into the stomach. Its chief work is in conducting the food from the mouth to the stomach.

The stomach is a large pouch placed in the upper part of the abdominal cavity under the diaphragm. It is convex on one side and concave on the other. The œsophagus opens in the middle of the stomach, and the small intestine starts from its right extremity. The passage connecting the stomach and the small intestine, is called the *pylorus* or 'the gate'. By the constriction of the muscles around the pylorus, the passage becomes closed ; and the contents of the stomach are thereby prevented from passing into the small intestine till they have been thoroughly exposed to the action of the gastric juice in the stomach and had been thoroughly churned. When this process has been completed, the gate reopens.

The gastric juice given out by the glands of the stomach, contains hydrochloric acid and certain enzymes called *pepsin* and *rennin.* The gastric juice acts on the proteins of the foodstuff and converts them into soluble peptones, but it has no action on starchy matter. Therefore, if too much of starchy food and too little of protein food be taken, the hydrochloric acid in the stomach, having no substance to combine with, remains in a free condition and this gives rise to what is known as hyperacidity. In such cases doctors prescribe lime water, or bicarbonate of soda for chemically neutralizing the acid, or some protein food like a hard boiled egg for the gastric juice to act upon. Rennin in the stomach curdles the milk taken, and this is necessary for assimilation of milk.

The food thus treated and converted into soluble forms passes into the intestine. The intestine is a long tube about five times the length of the body and follows a winding course. It is divisible into two portions—the small intestine and the large intestine. The two portions are different in width and perform different functions. The intestine is kept suspended within the abdominal cavity by a fold of membrane known as *mesentery*.

The small intestine is 20 ft. in length and nearly one inch in diameter. The first portion of the small intestine adjoining the stomach is known as the *duodenum*. The duodenum at a little distance from the pylorus, receives a common duct through which secretions of liver, gall bladder and pancreas flow into it.

The liver is a large organ which is divisible into two large lobes. It is an important organ, and stores up the *glycogen* or the animal starch. Moreover, it converts the nitrogenous products into urea. The urea is subsequently eliminated with urine by our kidneys.

The liver secretes a substance known as bile, a yellowish green liquid. The bile either flows through its own duct which opens into the common bile duct, and thence into the duodenum, or is stored in the gall bladder. The gall bladder also communicates with the common bile duct, and the bile stored therein flows into the duodenum when required. The fat contained in our foodstuffs when acted upon by the bile, turns into a soapy or emulsified solution, capable of being absorbed by the small intestine. Bile has also certain antiseptic properties.

The pancreas has a duct of its own, which opens into the common bile duct and this is in communication with the duodenum. The secretion of this organ called the pancreatic juice contains various substances, one of which is an enzyme called *trypsin*. This trypsin acts, like pepsin, on

proteins that have escaped the action of the gastric juice and converts them into peptones.

The wall of the small intestine contains glands which secrete a juice known as the intestinal juice. This intestinal juice contains an enzyme called *erepsin* which converts peptones into products known as *amino-acids*. It also contains certain substances which act on starchy matter as well as on fat and protein. It is thus clear that any foodstuff that has escaped conversion while passing through the various upper parts of the digestive tube, undergoes in the small intestine further treatment and is ultimately turned there into the nutrient or the tissue food. The food is now sufficiently prepared for absorption by the wall of the small intestine and is rendered fit for transportation by blood.

The process of absorption of the products takes place in the following manner.

The wall of the small intestine gives off finger-like processes called *villi*. The villi project into the cavity of the small intestine containing nutrients. The villi are richly provided with blood capillaries. Blood streams through them and picks up the nutrient products and later transports them to other tissues; while nutrient products known as amino-acids are thus absorbed by the blood from the intestinal villi, the emulsified fat or the soapy solution is not directly taken up or transported by blood and, therefore, is to be distributed in a different way.

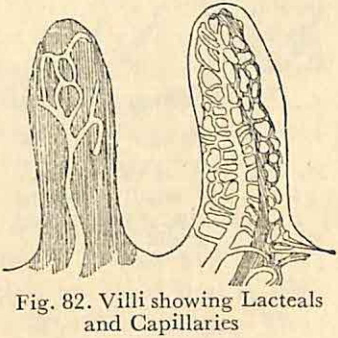

Fig. 82. Villi showing Lacteals and Capillaries

There are very narrow passages within the intestinal villi,

called *lacteals* which are different from veins or true blood-vessels (Fig. 82). The soapy solution passes into the lacteals and thence through a passage called the thoracic duct, so as to reach a big vein (Fig. 84). The lacteals resemble lymph-channels but differ from them in containing the soapy solution. The soapy solution is milk-white in colour and is known as *chyle*. Since the thoracic duct opens into the vein, the transformed fatty food ultimately gets into the blood stream and is transported to different tissues of the body like other products but only by a circuitous route.

The larger intestine is about 6 ft. long and about 3 inches in diameter. The large intestine immediately after its junction with the small intestine, dilates into a small sac called the *cæcum* (Fig. 83). The cæcum gives off a finger-like blunt process called the *appendix*. This often cause by its inflammation the disease known as the appendicitis. The large intestine ascends up to the lower surface of the liver, then proceeds transversely to the left and then descends. It is called ascending, transverse, or descending colon, according to the direction it pursues within abdominal cavity (Fig. 81). Larger portion of water is absorbed by the large intestine, while the residual or undigested food

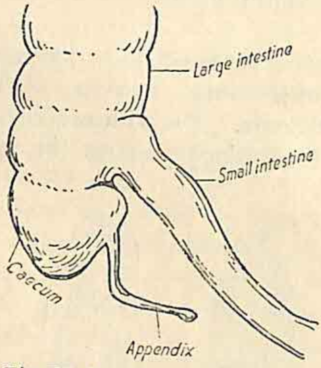

Fig. 83. Junction of the large and small intestine showing Cæcum and Appendix

matter assumes the character of fæces. The large intestine continues below as the rectum and terminates on the anus.

Questions

1. What are the common foodstuffs we take and how do they nourish the body ?
2. What is the function of the liver ?
3. Describe the changes the food undergoes as it passes through different parts of the alimentary canal.

CHAPTER XIX
CIRCULATION AND HEART

Blood is composed of a liquid substance called *plasma* and of myriads of *corpuscles* or tiny cells. The corpuscles may be compared to little vessels floating on a stream of water. The corpuscles are of two kinds,—the *red blood corpuscle* and the *white blood corpuscle*. Both are tiny living cells composed of protoplasm. But the red blood corpuscle differs from the white blood corpuscle in not having a nucleus which the other has. The red blood corpuscle is spongy in texture and occurs in the form of a disc, and is about 1/3200 of an inch in width. It contains a substance called hæmoglobin which combines with oxygen when the blood passes through the lungs. The blood carries the oxygen to the tissues where combustion sets in, resulting in the generation of heat. The carbon dioxide produced of combustion is absorbed by blood, and is later given out when blood again passes through the lungs. Thus one of the works of the red blood corpuscles is to subserve the respiratory function.

The white blood corpuscle moves like an amœba and is 1/2500 of an inch in width. Its work is mainly defensive. If any bacteria or enemies of microscopic size, get into the blood, the white blood corpuscles attack and engulf them by sending out protoplasmic processes around them.

The plasma is a liquid holding many substances in solution. The function of the plasma is to transport nutrients absorbed from the small intestine to the different tissues, and to carry back the waste nitrogenous products such as urea formed in the tissues to a filtering apparatus like the kidney. The clotting of blood is also due to this plasma. One would have bled to death on receiving a cut anywhere in the body, if blood had not the property of clotting and thus sealing the wound. The plasma contains a substance called *fibrin* which, coming in contact with air, is changed into fine net-works that entangle the blood corpuscles and cause coagulation of blood. From this coagulated mass, a clear liquid called *serum* separates out. The serum has the inherent property of neutralizing poison or toxin thrown into blood by the disease-producing bacteria, and produces an antidote in excess of the amount needed for neutralizing the poison. Thus the natural curative power of the body is partially due to blood or rather to the plasma of the blood.

Blood, moreover, acts as a vehicle for distributing *hormones* or internal secretions which are elaborated in glands like the *thyroid* and the *pituitary* which have no ducts of their own.

Blood flows through a system of fine tubes called blood-vessels. A pump is connected with these tubes. The heart represents this pump. The blood-vessel leading out of the heart is called the *aorta* or the big artery. The aorta gives off blood-vessels in different directions of the body. These blood-vessels are known as arteries and distribute blood to

different tissues of the body through the capillaries (Fig. 84).

Blood is carried back from the tissues to the heart by another set of blood-vessels called *veins*. Small veins open into a larger vein, or *vena cava*, which finally opens into the heart.

The heart is a large, hollow sac having muscular walls. The sac is divided inside by a partition into a right and a left cavity. Each cavity is divided into an upper and a lower chamber (Fig. 84). The upper chambers are called *auricles* and the lower chambers are known as *ventricles*. The auricle of each side communicates with the ventricle of that side (Fig. 85); but there is no direct means of communication between the chambers of one side and those of the other.

The big veins open into the auricles, and the big arteries arise from the ventricles (Fig. 86). The auricles collect blood and ventricles drive it out.

Each artery on reaching a tissue, such as a muscle or the brain, breaks up into several fine tubes or net-works of blood-vessels called *capillaries*. The capillaries run through the tissue and unite again to form a vein. Thus corresponding to each artery there is a vein; and these two vessels are connected with each other by capillaries. The capillary as the name implies is no thicker than the finest hair and is finer than the finest of any artery or vein.

The wall of an artery is composed of muscular and elastic tissues and is thicker than that of a vein. While the wall of a vein is thinner than that of the corresponding artery, the cavity or lumen of a vein is wider than that of the corresponding artery. Owing to the difference in the elasticity of the wall, a vein collapses when empty, but an artery does not. The blood contained in an artery is scarlet red as it is rich in oxygen while that of a vein is purplish blue as it is poor in oxygen and rich in CO_2. The arterial

blood is loaded with tissue-food on its way to the tissues, and venous blood is loaded with waste products of tissues on its journey to the heart.

Whatever may be the difference between an artery and a vein. blood contained in these blood-vessels, cannot escape through their walls so as to come directly in contact with the tissues. Each capillary has a very thin and fine wall through which an interchange of substances between the blood therein and the surrounding tissue, takes place. This is possible because the fluid portion of the blood oozes out through the wall of the capillary and diffuses through the tissue. The fluid is lymph which is blood minus the corpuscles. The flow of blood through the net-work of capillaries is very sluggish ; the blood returns to the heart by way of the vein (Fig. 84).

The lymph which has oozed out and bathes the tissues, returns by a different route altogether. It passes through channels called *lymphatics* which open into a passage called the thoracic duct. The thoracic duct, as mentioned before, opens into the big vein carrying blood from the head and neck region of the body to the heart (Fig. 84). Thus the lymph, too, passes back into the blood, but by a circuitous path.

The blood returning to the heart loaded with waste products, should be purified before it is again sent out by heart to the tissues needing fresh supplies of food and oxygen. Now the venous blood from the lower portion of the body on its return journey, travels through the kidneys where the nitrogenous waste products are eliminated. The blood thus purified opens into the large vein called the inferior *vena cava* (Fig. 84).

Blood collected from the intestine and stomach, passes through a vein into the liver and there the vein breaks up into capillaries. These capillaries unite again to form the

hepatic vein which opens into the inferior vena cava. Ordinarily a vein once formed by the union of capillaries does not break up into capillaries again but opens directly

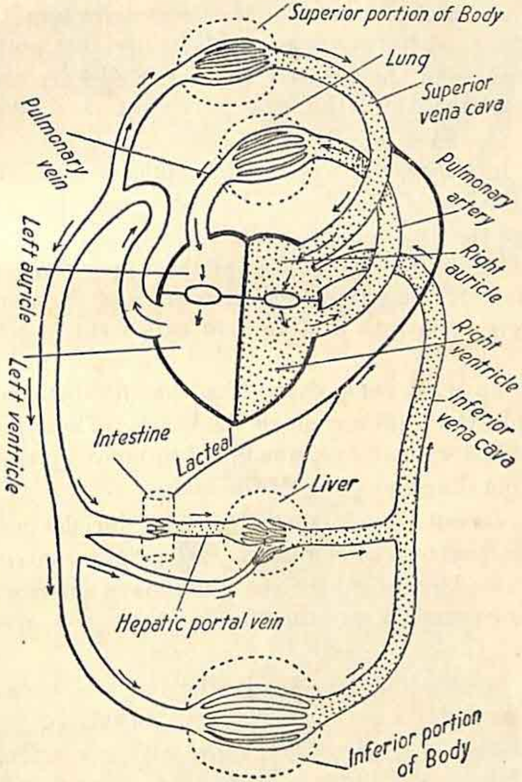

Fig. 84. Diagram of circulation and course of blood through Blood-vessels and Heart

into a large vein. But in the case of the vein bringing in blood from the intestine to the liver, it is broken up first into capillaries in the liver and then these capillaries

unite again to form the hepatic vein. Owing to this peculiarity the vein passing into the liver is called the *portal vein.* The portal vein carries blood which has absorbed nutriments from the duodenum. In consequence of the existence of the portal system the liver is supplied with the venous blood by the portal vein, as well as with the arterial blood brought by an artery. The liver has thus the peculiarity of a double blood supply.

The inferior vena cava which collects blood from the lower portion of the body, finally opens into the right auricle of the heart as shown in the diagram.

Veins bringing in blood from the upper portion of the body, namely the brain, neck, thorax and the upper limb, ultimately open into a large vein called the *superior vena cava.*

The superior vena cava, like the inferior vena cava, opens into the right auricle of the heart. The right auricle is thus filled with the venous blood brought by the two big veins from different parts of the body.

The venous blood from the right auricle passes into the right ventricle of the heart. The right ventricle sends this venous blood through the pulmonary arteries into the lungs for oxygenation of the blood and elimination of carbon dioxide.

The blood after aeration in the lungs returns through the pulmonary veins into the left auricle of the heart. The left auricle is, therefore, filled with the arterial blood received from the lungs. From the left auricle (Fig. 85) the arterial blood now passes into the left ventricle whence it is forced out into the aorta and thence through arteries to the tissues. Thus the right side of the heart, namely the right auricle and right ventricle, contains venous blood, and the left side of the heart the arterial blood.

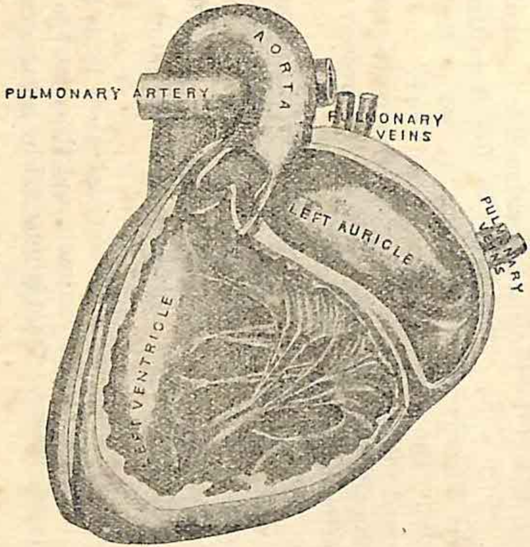

Fig. 85. Left section of Heart showing left Auricle, Ventricle, Aorta and Pulmonary Veins and Valves

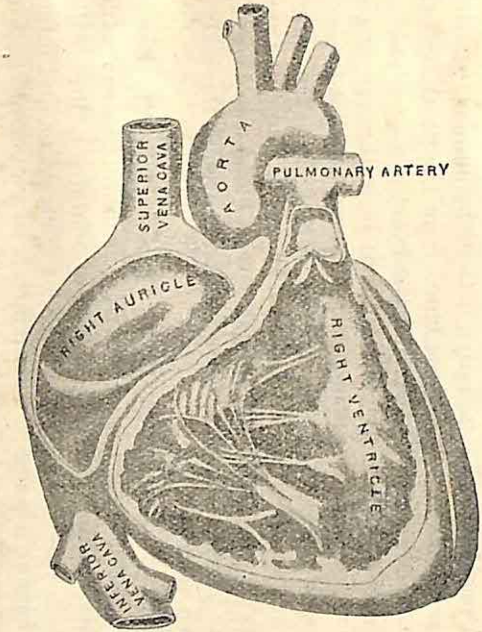

Fig. 86. Right section of Heart showing right Auricle, Ventricle and Valves

A peculiarity worth noting is that the pulmonary artery is carrying away the venous blood from the heart, and the pulmonary vein is leading into the heart the arterial blood from the lungs. In ordinary cases it is the artery that carries arterial blood which is rich in oxygen, while a vein is gorged with venous blood poor in oxygen. The case is the reverse here. A blood-vessel, therefore, is defined as an artery or a vein according as it carries blood away from or to the heart. The streaming of blood through the body is known as *circulation*.

The heart lies between the two lungs within the thoracic cavity, and is enclosed by a thin membranous sac called the *pericardium*. The pericardium contains a fluid called the pericardial fluid. The heart by contraction and dilatation acts as a pump. This pump is so important that its failure means immediate death. The portion of the heart containing the auricles is broader than the opposite or the apical portion. The passage of communication between the auricle and the ventricle on either side is guarded by a valve. Such valves allow blood to flow from the auricle into the corresponding ventricle, but not in the reverse direction. The ventricle on each side opens into a big artery and this opening is also guarded by valves (Figs. 85, 86). Blood will flow from ventricles to arteries but not from arteries to the ventricles.

The wall of each ventricle is stouter than that of the corresponding auricle. The ventricles pump blood into the aorta or an artery while the auricles are filled with blood brought by the vena cava or a vein. The right auricle receives the superior and inferior vena cavæ.

The blood from the right auricle passes into the right ventricle as the auricle contracts and the ventricle dilates. The passage between them is guarded by a valve called the

tricuspid valve (Fig. 86). The valve is in the form of three flaps the ends of which are tied by means of cords to the internal wall of the ventricle. The valve admits blood from the auricle into the ventricle, but not in the reverse direction as mentioned before.

The left auricle receives four pulmonary veins, two from each lung.

The passage between the left auricle and the left ventricle is guarded by a valve which is of the same disposition as on the right side. It is, however, composed of only two flaps ; hence it is called the *bicuspid* valve.

The pulmonary artery arises from the right ventricle and the opening is guarded by a valve called the *semilunar* valve composed of three pockets shaped like a half-moon. The pockets turn towards the pulmonary artery. As the blood from the artery tries to get back into the ventricle, the pockets are filled with blood and swell up choking the passage. Blood from the ventricle thus can pass only in one direction, namely, into the artery. The aorta arises from the left ventricle. Its entrance is also guarded by a semilunar valve.

The course of circulation of blood through the heart can thus be summarized. The impure blood brought by the veins flows into the right auricle and it is sent out by the right ventricle into the lungs. The blood from the lungs is brought by the pulmonary veins into the left auricle and passes into the left ventricle. The left ventricle sends it out through the aorta.

First, both the auricles contract and the two ventricles relax. Blood flows from the auricle into the corresponding ventricle. Then both the ventricles contract, driving away blood into the arteries, and both the auricles dilate and become filled with blood from the veins. The contraction

of the chambers of the heart, is called *systole*, and the dilatation or relaxation, *diastole*. A long pause intervenes between the contraction and the relaxation. The average number of heart's beats per minute may be taken as 72. A distinct sound called the heart sound is produced when the heart is in action.

Questions

1. Describe the course of circulation through the heart in man.
2. What role do the blood corpuscles play in the body ?
3. Distinguish between artery and vein.

PART IV

GEOLOGY

CHAPTER I

A STUDY OF THE EARTH

The solid land around us hides strange mysteries beneath its surface and itself presents many curious features. We wonder what force beneath our feet causes an earthquake or a volcanic eruption ; what makes the ground hard and rocky at one place, and sandy or earthy at another ; why the ground at one place forms a hill, a mountain or a plateau, or why it is high or low ; why in one country the ground yields coal, or gold, or silver, or petroleum, and why at another we find none of these.

There are people called geologists, who have been studying the various features of the earth in order to find out answers to such questions. You will now learn something of what they have to tell us.

Do we live on soil ?

We are used to feel as we tread on soil that the earth underneath is made of soil only. But it is not really so. Go to a hill or a hilly country and you will find that the ground is composed only of solid rocks with small patches of earthy or soil matter here and there. In fact, where you find soil under your feet, you may be sure that there is hard rock beneath it, generally at a small depth but occasionally at very great depths, too. In other words, soil forms merely an outer coating with hard rocks beneath (Fig. 87).

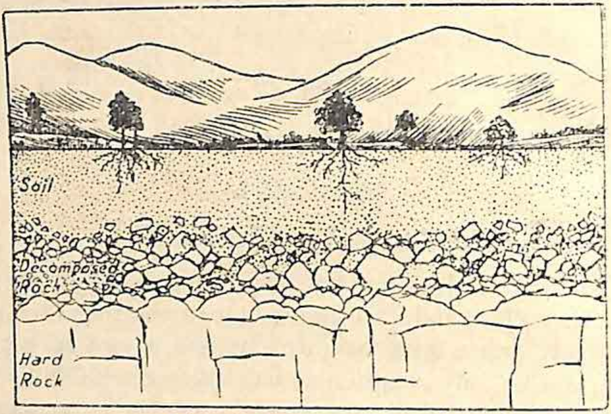

Fig. 87. Soil and Bed Rock

What is a rock?

A rock is built by nature. It is generally solid and hard like grinding stone, but it may also be loose like sand. On a careful examination we find that every rock is composed of small grains of one kind or different kinds. Each kind of such grain is called a mineral : *quartz*—the commonest material of sand-grains, *calcite*, i.e., the principal material of marbles, *augite, hornblende, mica, feldspar, ruby, diamond,* etc. ; these are few examples of minerals. In some rocks the grains of the minerals are quite big, while in others they are so small that they can only be seen with the help of a microscope. A microscope is an instrument which magnifies minute objects rendering them distinctly visible.

Different kinds of rocks—

Rocks are of various types which, however, may be grouped into three principal classes ; *igneous, sedimentary* and *metamorphic.*

How to know a sedimentary rock—

Sedimentary rocks lie in strata (Fig. 88), which are arranged either straight or curved, and their mineral grains are often rounded. They may also contain petrified remains of animals or plants, called *fossils*. Sedimentary rocks are usually composed of calcareous (limy) material, clay, sand grains, and also of large or small pebbles.

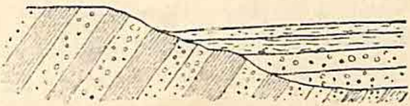

Fig. 88. Sedimentary Rocks lying in Strata—One set horizontal, the other tilted

Sedimentary rocks, as we find them in nature, resemble some rocks that are in the process of formation by the accumulation of sediments under the waters of the seas and lakes. They likewise must have been, therefore, formed similarly under water by sedimentation, and hence are called sedimentary i.e., produced from sediments.

Common examples of sedimentary rocks—

Sandstone, shale, limestone, coal, etc., are familiar examples of sedimentary rocks. Sandstone is composed of sand grains ; grinding stones are made of this rock. Shale is composed of clayey material. Limestone is composed of what the chemists call calcium carbonate, a calcareous material, which when burnt gives lime. Coal is formed when plants are buried under ground and are changed by heat and pressure. Sheets (or beds, as they are called) of clay or of sand deposited on the banks of a river, are also scientifically called sedimentary rocks. Sedimentary rocks occasionally contain valuable materials such as iron, manganese, gold, platinum, etc.

How to know an igneous rock—

Igneous rocks do not lie regularly arranged in strata like the sedimentary rocks. They lie in irregular masses of various shapes. They may occur in various forms :—wall-like bodies called *dykes* (Fig. 89) running across sedimentary

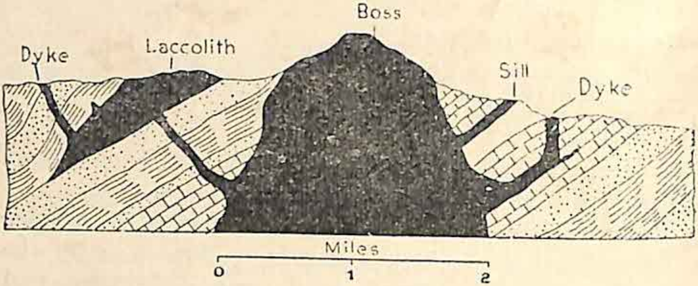

Fig. 89. Igneous rocks

beds or other rocks ; sheet-like masses called *sills* (Fig. 89) sandwiched between two beds of sedimentary rocks ; large lenticular masses, called *laccoliths* (Fig. 89), lying usually between two strata of sedimentary rocks ; flat sheets miles-wide, called *flows*, (occurring) on the surface of the earth ; and huge hummocky masses, called *bosses*, (Fig. 89).

The igneous rocks are composed of mineral grains which are often coarser than those of sedimentary rocks. They never contain fossils.

From the nature of the mineral grains of igneous rocks, geologists infer that they must have been formed from hot molten material. In fact some of the igneous rocks are identical with those rocks, which are found in volcanic regions and which are known to have been formed from the hot molten material called *lava* that comes out of volcanoes. Rocks produced from the lava of volcanoes are mostly black in colour and are composed of minute grains. Such rocks

are called *basalts* and usually consists of feldspar and augite and occur in the form of flows. Basalts are commonly used in road-metalling.

Molten rock-material does not always come to the surface of the earth, but may also solidify at great depths below the surface. In such cases it forms coarse-grained rocks, the commonest of which is called 'granite' of which the essential constituents are quartz, feldspar and mica. It is often used as pillars in magnificent edifices.

Many useful materials such as mica, copper, gold, silver, etc., are obtained from igneous rocks and also from rocks surrounding them. The forms of rocks as laccoliths, bosses and dykes are called 'intrusions'. As they are formed below the surface, they can actually be observed only when the rocks covering them have been 'eroded' away.

How to know a metamorphic rock—

Metamorphic means changed. In metamorphic rocks you may often find the mineral grains arranged in many fine bands (Fig. 90) or lamellæ. They are usually formed at considerable depths below the surface originating from a sedimentary or an igneous rock and changed by heat and pressure. They are usually coarser-grained than the original rocks from which they are derived.

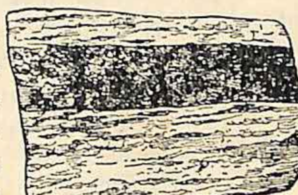

Fig. 90. Bands in a small piece of gneiss

Slate is thus produced from shale, marble from limestone, and quartzite from sandstone. A *schist* is a metamorphic rock which shows a tendency to separate into more or less perfect plates or laminæ, and a *gneiss* is one which shows bands of different colours and composition at the exposed surface (Fig. 90).

How rocks decompose or rot—

In rocky countries you will generally find that the outer portion of a mass of rock is rather loose and looks rotten. Break it, and you will find that the rock inside is compact and fresh.

The sun's rays heat the different minerals of a hard rock, and cause them to expand to different degrees. At night, on the other hand, cold contracts the minerals to different degrees. The minerals of a rock thus expand and contract alternately, and a strain is gradually set up in the rock. At length the rock is unable to bear the strain, and cracks at different points. Rain-water, holding oxygen and carbon dioxide in solution, finds its way into these cracks, and begins to eat into the rock. In very cold countries the rain-water inside the cracks freezes at night, expands and so pushes the walls of the cracks till the rock crumbles.

In this way the mineral-grains of a hard rock are loosened, and the rock looks rotten or decomposed. The broken pieces and particles of rocks are found scattered by the side of the main mass of rock in the form of rockwastes.

Along rocky sea-coasts and in rocky deserts, strong winds blow grains of sand against hard rock masses and wear them away. Waves of the sea dashing against rocks also break them down.

Roots of plants, too, growing on rock masses tend to loosen their constituent mineral grains.

Thus rocks do not always keep fresh and compact, but tend to be decomposed, broken, and eaten away.

The resting place of rockwastes, erosion and denudation—

On sea-coasts the loosened rock materials are washed away by the waves of the sea. On land the rain-water carries away the rockwastes formed on the hills and

plateaus, to lower levels and thus brings them down to rivers. On the lofty heights of snow-covered mountains, the glaciers (moving masses of ice) bring down the rock-wastes, and as they melt, the water flows as mountain streams bearing the rockwastes.

All rivers carry fine particles as well as larger pieces of rocks in this way. In times of flood these materials are deposited on the banks of the rivers as sediment or silts.

In some places strong winds carry away finer rock-wastes from one region to another. The sands of the desert in Rajputana are believed to have been borne by winds from the coasts of the Arabian Sea.

While a river is carrying forward the sediments, all the particles borne in the stream dash against one another and become gradually finer and their surface-irregularities are rounded off.

When the river leaves the higher regions and flows through comparatively flat countries it loses speed, and the coarser grains of sediments get deposited in the bed of the river or by the side of it. When the river reaches the sea, its flow is completely checked, and the sediments are laid on the sea-bottom.

Land areas—high grounds in particular—are, being continuously worn or 'eroded' away in this way, and rocks underlying them are being laid bare or 'denuded'.

Formation of sedimentary rocks—

Every flood brings a fresh heavy load of sediments, which go on accumulating year after year. A land formation is, in this way, being built up under the waters of the sea. In course of time this piece of land grows so high that it rises above the surface of the sea-water and forms a new land. The Sunderbans area has been built up in this way from clayey sediments brought down by the Ganges and the

Brahmaputra. The old rivers go on building up new lands further down the sea. A delta is formed in this way near the mouths of the rivers.

When the sediments are accumulating under water, their bottom layers get gradually pressed by the weight of those overlying, and in course of time these harden into solid sedimentary rocks. When marine animals die, their bones or similar hard parts of their body rest entombed in the sediments. In time, those bony remains are petrified so as to form fossils.

The sediments do not lie under the sea for ever—

The sedimentary rocks do not lie under the water of the sea for ever. Forces acting from within the earth, push or fold them up from the sea-bottom, the sea disappearing at the same time from that region. Sedimentary rocks which are seen on the surface of the earth have been forced up in this way.

How rock-strata are folded and faulted—

Further, when the sediments fall on the ocean-bottom they must lie in almost horizontal sheets. But very often we find that on hills or elsewhere the rock-strata are more or less tilted or bent and contorted in every imaginable way.

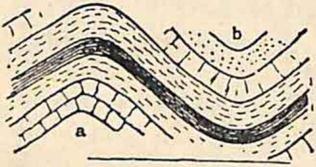

Fig. 91. Simple "Folding" in rocks

If you push several sheets of paper placed one on the other you will find that they buckle up. Sheets or strata of rocks, sedimentary rocks in particular, show similar bucklings. These rock-strata must have been therefore, put to pressure sideways. Such features in rocks are called 'folding' (Fig. 91), and each buckling is called a 'fold'. Folds may be of various shapes and

dimensions. Thus up-folded strata are said to form an "anticline" (as at *a*, Fig. 91) and down-folded strata are said to form a "syncline" (as at *b*, Fig. 91).

At some places you may also find large cracks within a rock, both sides of which are vertically displaced. Such phenomena are called 'faults'. They show that rocks may be broken and displaced by more or less vertical movements (Fig. 92).

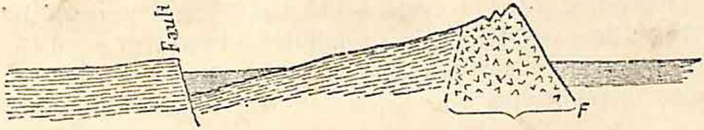

Fig. 92. "Faulting" in rocks

You know from all these that the ground we tread on is not in a stable state. There are forces acting within the earth, which cause movements in the crust of the earth, called earth-movements : the rock-strata are lifted up thereby from the sea-bottoms, tilted, folded and faulted, while portions of land subside under the sea-level elsewhere.

Can we feel the movements that take place beneath our feet ?

We can sometimes feel these movements when an earthquake takes place. Earthquakes indicate movements inside but they are very feeble movements, when compared to those which lifted up and folded the sedimentary rocks leading to the formation of huge mountains like the Himalayas.

Questions

1. Distinguish between a sedimentary and a metamorphic rock.
2. Describe how rocks are formed and become folded.
3. Why are fossils found in sedimentary rocks ?

CHAPTER II

EARTHQUAKES

How an earthquake is caused—

The movements of the ground in an earthquake are due to sudden shocks produced inside the crust. Scientists have found out that great earthquakes occur in the neighbourhood of huge mountains like the Himalayas and the Alps, where rocks are greatly folded and faulted, or in the neighbourhood of oceans where deep faults occur (like the coast of the Pacific near Japan). A slip of land along such a fault hidden deep below gives a sudden jerk to the ground on all sides of the fault. The shock of the jerk spreads round like a wave which is felt on the surface of the earth as an earthquake shock.

The earthquakes of Baluchistan (1892, 1931, 1935), and of Bihar (1934) are probably due to such causes. Minor quakes of the ground are felt during volcanic eruption, or are due to the falling down of huge portions of cliffs of a mountain or the collapse of the roof of an underground cave.

Why we are alarmed about earthquakes—

We feel alarmed about earthquakes because they are so sudden and terrible. They are felt only for a few seconds, but within that short time they ruin cities and villages and destroy hundreds of lives. The ground cracks under us, cultivation, roads and bridges are destroyed ; rivers are obstructed ; floods are caused ; and lands are locally upheaved or depressed. In a word, they cause devastation and panic.

Men of science are particularly interested in earthquakes, because they have found out many facts concerning

the interior of the earth by studying the earthquake shocks. But it is unfortunate that we cannot fight with an earthquake. We do not know when it may occur, and where. About the latter fact you may know this much that it is likely to occur generally in areas bordering on folded mountains like the Himalayas, and on some ocean coasts like the Pacific coast.

Dangerous hill-slopes—

In an earthquake the jerking of the ground may sometimes cause a rather big portion of a hill to fall down on the ground below. Such falling down of large masses of rocks are called 'land-slips'.

Land-slips are, however, more commonly caused in a different way. When the rocks on a hill-slope are finely banded, or arranged in lamellæ or strata, and when the bands, lamellæ or strata are inclined in the same direction as the slope of the hill, the bands, lamellæ and strata tend to slide down. If, in addition, rain-water finds its way along the bands, or into the cracks and pores of the rock, the rock-mass becomes loose, and there is the greater chance of land-slips.

In Darjeeling, Simla, and other hill-stations in the Himalayas such land-slips are common. They cause damage to hill-roads, the mountain railways and human lives and habitation.

VOLCANOES

If you ever happen to visit Japan, Java, Italy or some islands in the Pacific Ocean, you will find there conical hills called volcanoes, with funnel-like openings at their tops called *craters*, which are connected with the interior of the earth by means of pipe-like channels (Fig. 93). From time to time these volcanoes give out hot gases, broken pieces and particles of rock or hot molten materials (lava) through their craters. Such volcanoes are said to be *active* and the

ejection of material is called *eruption*. The erupted material which gather round the crater, build up the conical hill.

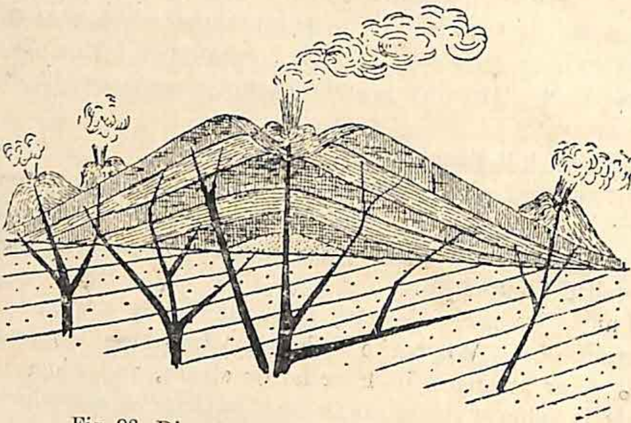

Fig. 93. Diagrammatic section through a Volcano: Black masses represent molten lava

Some of the volcanoes are of quiet nature because they silently pour out streams of lava which overflows the crater, spreads out, cools and is converted into a solid rock which is usually a 'basalt'. Several volcanoes in the Hawaii Islands in the Pacific Ocean belong to this type. The largest of them is called Mauna Loa and the smaller one, Kilauea.

There is a second type of volcanoes which are violent and explosive in nature. After long intervals of time they begin to send forth hot gases, and then burst into a violent explosion destroying the mountain-tops; they eject huge quantities of dusty rock-material and shoot large pieces of rock into the air. These materials are scattered over miles and miles of the surrounding countries causing great damage to vegetation, and animal life. The biggest of such explosion was made by the volcano called Krakatoa which is situated near Java.

But most of the volcanoes of the world, after intervals of quietness, make an explosion and afterwards begin to pour down streams of lava. The well-known Vesuvius is an instance of this type of volcanoes.

When an active volcano is not in action for an interval of time, it is said to be *dormant* ; and when it has lost its activity for ever, it is said to be *extinct*. But it is difficult to say whether a volcano is extinct or not, even when it has not been in action for a long time.

Where volcanoes occur—

Broadly speaking, most of the volcanoes of the world are arranged in two belts on the surface of the earth, one lying along the coast of the Pacific Ocean, and the other across the Atlantic Ocean from the West Indies, through the Mediterranean Sea, Central Asia, to Java and Sumatra in the East Indies. These two belts are weak in nature, because large deep faults occur along them beside the ocean basins. In these weak zones of fault, hot molten material is forced up from the interior of the earth by the pressure of overlying rocks and of the gases within the hot material itself. In India there are no active volcanoes.

What extinct volcanoes tell us—

In many parts of the world there are hills and plateaus made of basalt (a rock which we know to be the product of volcanoes). The Deccan plateau is a notable example ; a large portion of it is made up of basalt flows. All the living volcanoes pour out lava, which, when consolidated, produces mostly basalt. These observations lead to the belief that everywhere beneath our feet at some great depth likely there is a continuous store-house of hot basaltic material.

The changeful surface of the earth—

You have seen that the rocks of the land are continuously being worn away, i.e., 'eroded' by the action of air, water,

ice, river, wind and sea-waves ; volcanoes destroy portions of hills ; earthquakes produce cracks, faults and land-slips ; earth-movements cause depression of land areas. On the other hand volcanoes build up hills and plateaus made of erupted materials, rivers, build new lands beneath the waters of the sea ; and earth-movements build mountains, hills and plateaus. In this way the surface of the earth is continually being changed, old features are being destroyed and new ones come into being. These processes had been also going on in the past, and so the surface of the earth did not look the same in the past as it is now.

By studying the rocks geologists have found out the changes which the surface of the earth has undergone during the past years. They have been able to trace in this way the history of the surface of the earth. They consider that the oldest surface of the earth was made up of igneous rocks only. As igneous rocks are produced from hot molten materials, the surface of the earth in very olden times must have been all hot and molten like the interior of an active volcano of the present-day.

A question naturally arises whether long long ago the earth had been altogether a molten mass. The surface of the earth is now solid, and you know that a liquid material becomes solid when it loses heat. The earth has been therefore, losing heat in the past. It must have been hotter then, and still hotter in still earlier times. Heat converts a liquid into gas. Was ever the earth gaseous before it has taken to liquid state ?

Questions

1. What are the different types of volcanoes ? Wherefrom does the lava come ?
2. Why do earthquakes occur ?
3. Why is the surface of the earth changing ?

CHAPTER III

THE EARTH

The birth of the earth—

Astronomers, who know more about the birth of the earth, her movements, shape, and such other particulars, tell us that the earth originated from a hot gaseous body.

They say that once a giant star, much larger than the sun, happened to pass very near the sun, and as it passed, it pulled off a huge portion of the sun's gaseous material in the form of a bent cigar. The star moved away before this gaseous mass could be drawn back into its body. So the mass of gas was left out in space within the influence of the sun, and in course of time this broke into several huge balls which went in revolving round the sun as so many planets. The earth is one of them.

Scientists reckon that all this happened nearly 2,000—3,000 million years ago. So, when the earth was born out of the sun, it was a hot gaseous mass. Gradually it cooled down by losing its heat, and in course of time changed into a liquid ball. The surface of the earth must have been the first to cool and turn into liquid. The liquid earth also went on losing heat and in course of time the outer portion of the earth became solid. This solid outer portion of the earth is now called the 'crust' of the earth. We live on this crust.

Men of science tell us that, when rocky and metallic materials are melted together, the molten rocky materials being lighter float on the metallic materials.

We expect, therefore, metallic materials to be present beneath the solid, rocky crust of the earth.

Inside the earth—

You have already found reasons to believe that at some depth under the surface of the earth there must be hot basaltic materials in all parts of the globe.

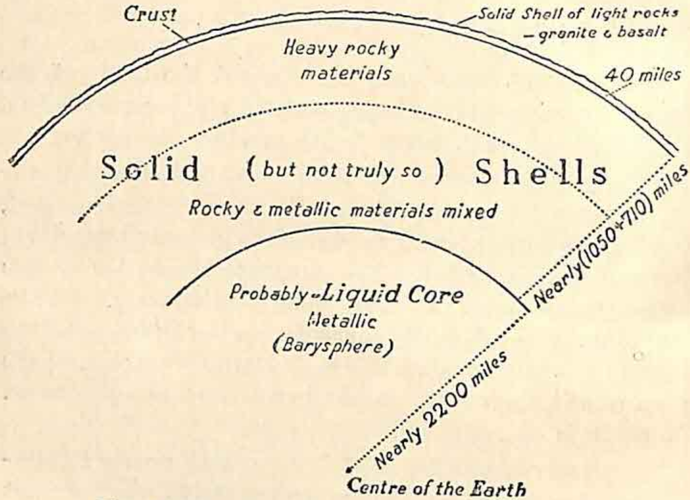

Fig. 94. Hypothetical section through the Earth

Scientists have determined that the earth as a whole is nearly $5\frac{1}{2}$ times heavier than an equal volume of water. They have also found out that rocks of the outer portion of the earth as well as the basaltic materials in the lower portion are each about 2·8 times heavier than water.

These facts have led them to the conclusion that the material inside the earth consists, nearer the surface of rocky materials which is heavier and denser at greater depths, and that the central portion of the globe is composed of a material, which is nearly 10 times heavier than water. This material is probably made up of mixture of iron and nickel. We have seen above that the present theories about the

origin of the earth also support the above conclusion about the presence of metallic substances inside the earth.

They have further obtained evidences from the study of the earthquake-shocks that the earth is a sphere composed of more or less distinct shells of different materials one covering the other (Fig. 94).

The central portion is a spherical mass made of iron and nickel. It is probably in the liquid state and is about 2,200 miles in radius.

Around this core is a shell, nearly 1,050 miles thick, composed of mixture of metals and heavy rocky materials, and a second one, about 710 miles thick, composed of heavy rocky materials only. These two shells appear more or less solid, but are not really so. They are more like the common road pitch, or sealing wax, than granite, basalt, or sand-stone.

The outermost shell lies nearly 40 miles thick, composed of lighter rocks (basaltic in the inner portion and granitic in the outer). This shell is solid and tough, and is called the crust of the earth. On land granitic rocks predominate; the floor of the oceans are composed mostly of basalt.

Conditions within the earth—

As we go down in deep mines we feel hotter and hotter. The earth must be, therefore, hotter inside, a conclusion to which the hot condition of the lava poured out by volcanoes also points.

It is reckoned that at the bottom of the crust the temperature is nearly as high as 1,200°C. Near the centre of the earth the temperature must be enormously high.

Inside the earth the pressure increases with the depth, because the materials above, press on those below. It has been calculated that at a depth of 40 miles below the crust, the temperature is sufficient to melt the rocky materials

there, but at the same time the pressure is so great that it would prevent them from melting. The materials in those regions, therefore, are not in a perfectly solid state.

The usefulness of the knowledge of rocks—

A knowledge of the rocks of the crust is useful to us. Particular kinds of rocks contain particular metals and minerals. Thus mica, a useful mineral, is not found in sedimentary rocks, and it will be foolish to search for it in a country where the rocks are shale and sandstone.

Coal and petroleum are two substances which are almost indispensable to us ; they are our sources of power. They are found within sedimentary rocks under special conditions.

Questions

1. Discuss the origin of the earth.
2. Give a picture of the internal conditions of the earth.

CHAPTER IV

COAL AND PETROLEUM

Coal, its occurrence and uses—

You have learnt that coal is a sedimentary rock. It is found usually between strata of sandstone and shale (Fig. 95). The strata or seams of coal range in thickness from a few inches to hundreds of feet. Coal is obtained from these seams by digging large holes or boring mines underground, and by cutting away portion of the coal seams.

There are several qualities of coal. Purer forms of coal are used for extracting iron from ores, i.e., rocky materials,

in which iron is found in one form or other; they are required for producing steam and for various other purposes. Impure varieties are burnt in domestic ovens.

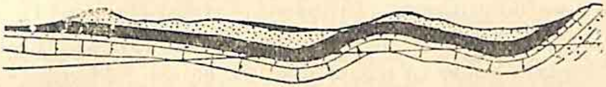

Fig. 95. A Bed of coal (the black band) within strata of sedimentary rocks

When powdered coal is heated in large narrow chambers made of iron, we get the gas for street-lighting and cooking, as well as napthalene, road-tar, and many other useful substances.

Coal is found in India largely in the very old sedimentary rocks in the valley of the Damodar river—in Raniganj, Jharia, Giridih, and in the neighbourhood, also in the Central Provinces, in Central India and Hyderabad. It is also found in some younger rocks in Assam, Baluchistan and in the Punjab.

How coal is formed—

Coal is found in nature intercalated between strata of sedimentary rocks, and impressions of plant leaves and other signs of former plant life are found there. Coal is, therefore, a rock which is formed from plant materials, deposited with the sediments. The heat and pressure underground, in course of time, changed these materials to coal.

Petroleum, its occurrence, uses and origin—

The petrol that propels automobiles, aeroplanes, etc. the kerosine that is so useful to us, the wax that is used in making candles, are all obtained from an oily substance that

occurs in nature within some sedimentary rocks. This oily substance is called petroleum.

Petroleum is a liquid substance made chiefly of carbon and hydrogen. It occurs within sedimentary rocks under particular conditions. In many parts of the world e.g., in the Punjab and Assam in India, and in Burma, there are sedimentary rocks of recent age, which are folded in simple curves. Petroleum occurs usually along these folds within porous sandstone strata having a cover of non-porous shale above it. It is associated with gas and water within the porous sandstone, the gas remaining above the petroleum (Fig. 96).

If indications on the ground are favourable the rock containing the oil is bored and the oil is forced up by the pressure of the gas in the form of a fountain (*W* in Fig. 96). Subsequently the pressure diminishes and the petroleum is pumped out. The petroleum, thus obtained directly from

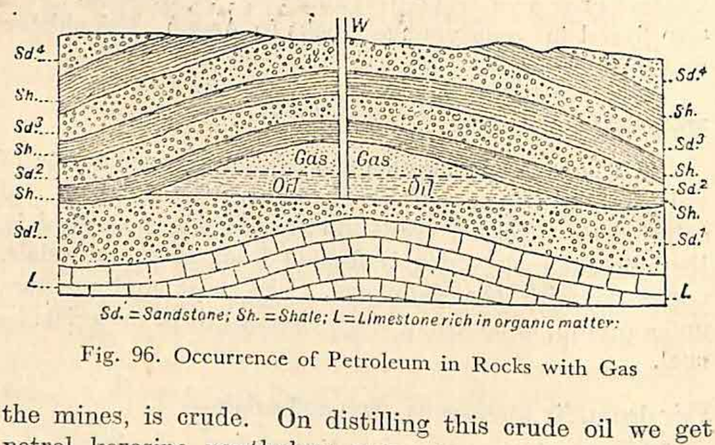

Fig. 96. Occurrence of Petroleum in Rocks with Gas

the mines, is crude. On distilling this crude oil we get petrol, kerosine, napthalene, wax, etc.

It is believed that petroleum is produced from the decay of underground vegetable and animal matter.

Soil and its varieties—

Soil is the earthy material we are treading on. Scientifically speaking, soil is a mixture of the products of decomposition of rocks and the decayed vegetable matter.

The products of decomposition of rocks either accumulate by the side of the parent rock or is carried away by wind, rain-water or rivers. In the first case the soil is called a *residual soil*. It is related to the underlying rock in composition. The black cotton-soil of Bombay is of this nature. It has been derived from basalts lying below. In the second case the soil is called a *transported soil*. A transported soil does not, as a rule, resemble the underlying rock in composition. It is of greater thickness and generally more fertile than a residual soil. The alluvial soils of the river valleys are formed of transported material.

Soils are composed principally of clayey, sandy and calcareous materials mixed together with decayed vegetable matter (*humus*) in different proportions. Besides these, there are present in soils water and mineral matters. Alluvial soils, which are found in the lower courses of rivers as in Bengal, are clayey ; in the upper parts of a river-valley the soil is generally sandy ; soils containing clay, sand, and humus are called *loams* ; those containing clay, lime and humus are called *marls*, and soils very rich in humus are called *muck*.

Soil and plant life—

Plants require water and some mineral matters dissolved in soil. Nitrogen, phosphorus, and calcium are the most important of these mineral matters.

All plants do not require the same kind of mineral food and all soils also do not contain the identical mineral matters. It is one of the reasons why the same plant can-

not be grown everywhere. Again, if a crop is grown in the same area repeatedly for years, it will take away from the soil that particular mineral food which it needs for its growth; the soil becomes very poor. The crop will then no longer grow well in the area unless a material which contains the mineral food in question is added to the soil. This is called *manuring*.

The nature of a soil affects cultivation in other ways, too. The constituent particles of a sandy soil are comparatively larger than those of clayey soils. Sandy soils are, therefore, more porous than clayey soils, and retain less quantity of water than the other. As water is essential to plant life, sandy soils poor in water are less suited to cultivation than water-bearing clayey soils. Sandy soils are again more quickly heated than wet, clayey soils. The consequence is that the former yield crops earlier, while the latter yield much later but richer crops. Hard soils are difficult to cultivate while softer soils are easier to till. Alluvial soils of river valleys are best suited for cultivation.

Questions

1. Where do we expect to find petroleum ?
2. How is coal formed ?

PART V

ASTRONOMY

CHAPTER I

A STUDY OF THE HEAVENS

Astronomers and their helping hands—

We see in the sky the sun and the moon as two shining discs and stars as shining little spots. But they are really enormously large in size, and full of wonders and mysteries. There are people, called astronomers who from the earliest times have been studying these heavenly bodies. With the help of special instruments, such as the telescope and the spectroscope, they find out the wonders and mysteries about them.

Distant objects viewed through telescope appear nearer, magnified and distinct. With the help of this instrument astronomers can tell us what the heavenly bodies really are, how they move, how far they are from us. By spectroscopic examination of light coming from heavenly bodies, men of science can find out what these bodies are made of, and how old they are.

Why we get day and night—

It is day when the sun rises in the east. In the evening, the sun sets in the west. Night follows and there is no sun in the sky. We get day and night, as the sun moves across the sky from the east to the west, passes beyond our view and again appears in the east next morning.

But men of science tell us that the sun does not move round the earth. Really it is the earth that spins like a top as it turns from the west to the east. The earth as it moves carries us gradually towards our east, and the sun

appears to move to the west ; we are not conscious that we are moving with the earth and so we apparently see the sun moving. The earth has in fact two motions. It rotates round its own axis. It moves round the sun.

Stars and the moon also rise and set—

As the earth spins or rotates on its own axis, against the hands of a watch, all objects outside the earth must necessarily, like the sun, appear at one time to rise in the east and to set at another time in the west. The stars and the moon do behave exactly in the same way. In the evening some stars are seen rising in the east, while others are seen setting in the west. Likewise the moon may be seen rising in the east or setting in the west.

So they all appear to move from the east to the west. If you observe a star through a small hole in your window for two consecutive days, you will find that it is visible through the hole after interval of nearly 24 hours (more correctly 23 hours, 56 minutes, 4 seconds). This is the time that the earth takes to make one complete revolution.

THE SUN

How far the sun is from us—

The sun is at a very great distance from the earth. If one could travel through the vast space to the sun at the rate of, say, 100 miles per hour, it will take about 106 years to complete the journey. Although the sun is not always at the same distance from us, we can say that the average distance is about 93,000,000 miles. This distance is so great that even light, which travels as fast as 186,000 miles per second takes about 8 minutes to reach the earth from the sun.

How large the sun is—

In the sky the sun looks like a large shining disc, and

we know how far it is from us. It must be, therefore, immensely larger than what it appears from such a long distance. The sun's bulk is in fact 1,300,000 times the bulk of our earth. The diameter of the sun's disc is really nearly 864,000 miles, whereas the diameter of our earth is only about 8,000 miles. The sun is to the earth what a large football is to a small grain of mustard.

What the sun really is—

The sun is really a huge spherical mass composed of extremely hot glowing gases. We see the outer portion of

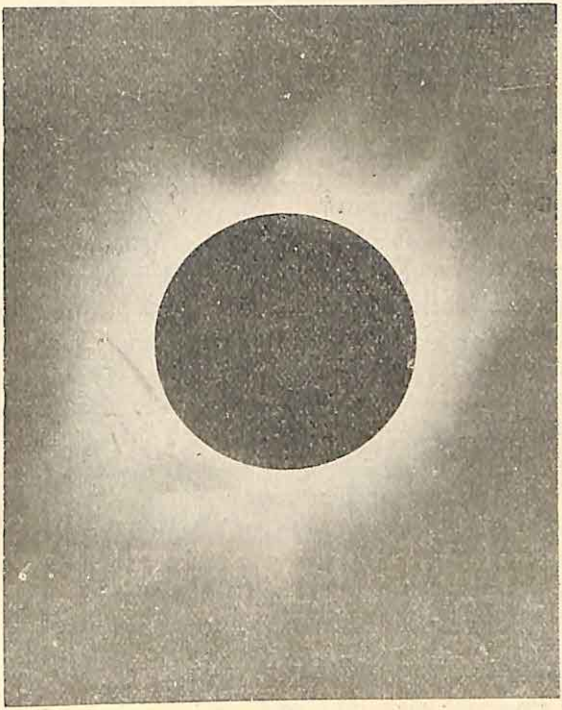

Fig. 97. Solar eclipse

this glowing mass. This is called the *photosphere*. Its temperature is nearly 6,000°C. We can realize how hot this is if we compare its temperature with our summer temperature in India which is about 35° to 50°C.

During an eclipse (Fig. 97) when the luminous disc of the sun, is covered in darkness, astronomers have observed a red gaseous envelope (*chromosphere*) around it with a region of rich glow (corona) outside the envelope. The gases of the photosphere and the chromosphere are always in violent agitation. On account of this, red flames are shot up thousands of miles high into space at terrific speed from the chromosphere, and cavities are formed within the gases of the photosphere. Seen through a telescope these cavities* look dark on the sun's brilliant disc and are known as sunspots.

THE MOON

Is the moon like the sun?

The moon is not a hot gaseous body like the sun. It is rather a cold solid globe, smaller than the sun and much nearer to the earth. Its average distance from us is about 239,000 miles. Its diameter (2,160 miles) is really 1/400th of that of the sun and nearly 1/7th of that of the earth.

The surface of the moon is made up of hills, craters and deep basins (Fig. 98). So it does not give us any light of its own. The silvery moonlight is really the sun's light reflected from the surface of the moon. The hills on its surface are illuminated as the sun's rays fall on them, while the craters remain dark. If you look at the moon carefully you can distinguish some of these features. You can of course see them clearer through a telescope.

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*Recent investigations have proved that they are not cavities but are spots near the sun's surface, which emit less light than the surrounding areas and hence look darker by contrast.

Observing the moon's phases—

If you watch the moon for an hour or two any day in the evening, you will find that it is moving to the west, just as the sun does. This movement of the moon is due to the rotation of the earth on its own axis.

Fig. 98. Photo of Half Moon

If you observe the moon the next day at the same hour, you will find that it is no longer in the same position, but has moved in the midst of a different group of stars, a little to the east of those amidst which it was seen on the previous day. When you find the moon pictured among

a group of stars, you must remember that moon is not really in the midst of them. As the moon slowly glides through the starry space, you see a background of stars very remote from the moon. This background changes from day to day, and the moon appears to move among the stars from the west to the east. This happens because the moon moves round the earth, always maintaining nearly the same distance from it. During its revolution

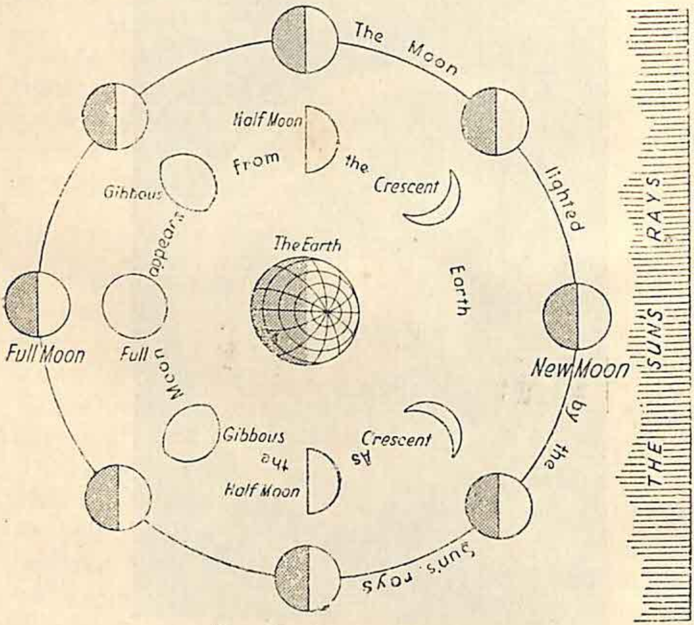

Fig. 99. Phases of the Moon

round the earth, the moon always presents the same face to it. This is the reason why we find the same features on the moon whenever we look at it. But on the other hand the moon would present to our view all the portions of its surface if we were stationed at a place situated some-

where in the space beyond its orbit, while it was turning round the earth. This means that the moon is rotating in space.

As the moon goes round the earth, its position with respect to the sun and the earth changes. If you daily observe the moon, some day you will find that it appears as a full disc and is rising in the east while the sun is setting in the west. It is then called the 'full moon'. Clearly, on that day the sun and the moon are on the two opposite sides of the earth (Fig. 99), but they are not exactly in the same straight line ; for the sun lights exactly one half of the moon (otherwise the earth lying between the moon and the sun would hide the sun from the moon) ; and on looking at the moon we are seeing exactly the same lighted half.

A few days later the moon is no longer a full disc. It is worn away at one side. The moon is not clearly now on the side of the earth exactly opposite to the sun (Fig. 99) ; for, when the sun sets to our west the moon is not to our due east ; it is now below the horizon.

Nearly eight days after the full-moon phase, the moon is exactly on the antipodal side of the earth by the time the sun sets ; it is at right angles to the line joining the earth and the sun (Fig. 99). We know this from the fact that on that day the moon comes exactly overhead nearly 12 hours after sunset (it must be exactly below our feet when the sun sets). The moon is now a half disc.

The wearing away of the moon continues, till four or five days later a crescent moon appears in the sky very late in the night.

Nearly fifteen days after the full moon, the moon and the sun set together in the west. Evidently they are now exactly on the same side of the earth (Fig. 99), but not exactly in the same straight line. You can see the sun setting, but as the sun illuminates the particular half of

the moon, which is now away from you, you would be facing the dark half of the moon (new moon) and you do not see the moon in the sky that night.

Two or three days later a crescent moon is seen in the western sky when the sun sets. About seven or eight days later you see a half-moon midway in the sky, and fifteen days later the moon is again full and it rises in the east at sunset.

The period of time between two successive full-moons is about $29\frac{1}{2}$ days. This is called *lunar month*. In Hindu astronomy this period of time is divided into thirty equal parts each called a lunar day or "tithi". You will note that the $29\frac{1}{2}$ days or the 30 lunar days make a lunar month ; so the two kinds of "days" are of different lengths.

Twelve lunar months, (i.e., 360 lunar days) or rather $29\frac{1}{2}\times 12$, i.e., 354 days make a lunar year.

ECLIPSE

How the moon is eclipsed or obscured—

You have learnt that at the time of full-moon the moon is not exactly in the same straight line with the earth and the sun. But occasionally it happens that on a day of full-moon the moon, the earth and the sun are exactly

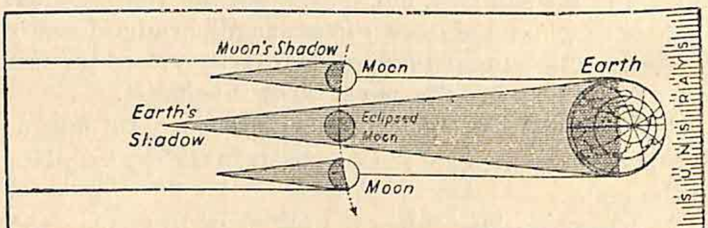

Fig. 100. Lunar eclipse

in the same straight line, that is, the moon is in the same plane as it passes through the sun and the earth. The earth, in such a case, obstructs the rays of the sun and

prevents them from falling on the moon. So the moon falls within the shadow of the earth and is not lighted ; it is then said to be eclipsed (Fig. 100).

How the sun is eclipsed—

Similarly, if the sun, moon and the earth happens to be on the same straight line and the moon comes between the earth and sun, the sun is hidden from our view and is

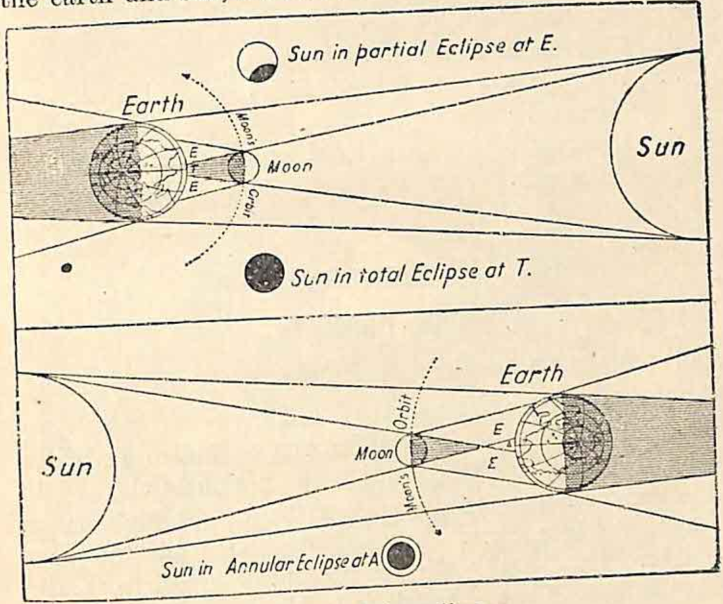

Fig. 101. Solar eclipse

said to be eclipsed. The moon, however, is a very small object compared with the sun. So it can hide the sun in full only from a very small portion of the earth's surface. People in these parts have total solar eclipse (Fig. 101). From other parts of the earth's surface the sun is partly visible, and there the people witness partial solar eclipse

(Fig. 101). It may sometimes happen again that the dark disc of the moon covers only the central portion of the sun's disc having a bright ring around it. The eclipse in such case is said to be *annular* (Fig. 101).

Questions

1. Explain why the sun daily rises in the east and sets in the west.
2. Describe the phases of the moon.
3. What is a lunar eclipse ? How and when does it occur ?
4. Distinguish between total and partial eclipse of the sun.

CHAPTER II

THE PLANETS

What the planets are—

The planets are some of the luminous specks which we commonly call stars. If you happen to find in a night a rather brilliant speck of light in the region of the sky in which moon is generally seen, you should go on observing it for a few days more. You will find that while the stars in other parts of the sky do not move apart from one another, but all move together to the west, this brilliant star moves slowly in the midst of other stars. Such moving or wandering stars are called 'planets'. All the other stars are called 'fixed stars' or simply 'stars'.

The fixed stars are at enormous distances from us ; their lights flicker or twinkle and look rather feeble. The planets are much nearer to us ; they are more brilliant than the stars and their lights are more steady.

How the planets move—

You have just seen that the planets wander among the fixed stars. You may also observe that they move at the same time to the west with the stars. This latter motion is not real, and is due to the earth's rotation. Astronomers

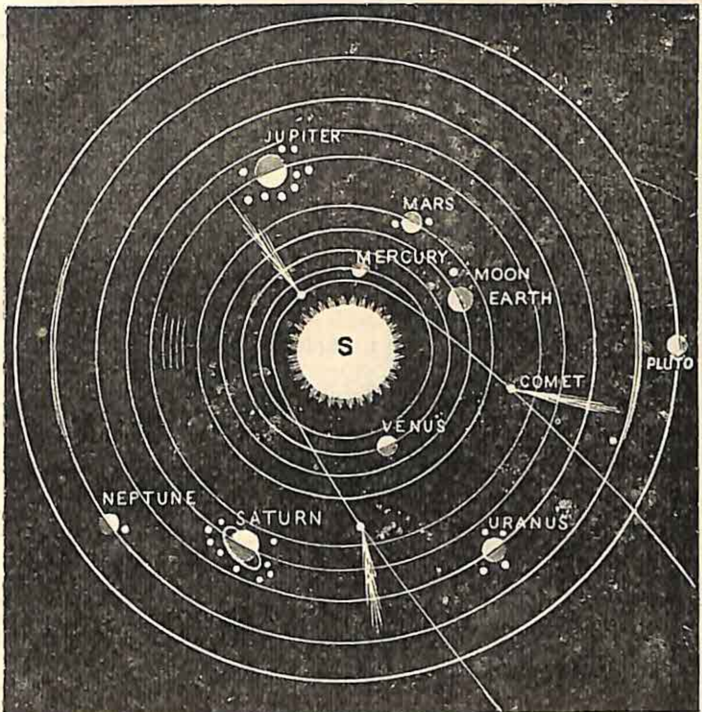

Fig. 102. Paths of the planets with the Sun and the Halley's Comet

have carefully watched the former movement also, and they say that the planets are seen moving among the stars in this way because they move around the sun in nearly circular paths, and that because our earth (which the astro-

nomers have found out, from its movements and other features, to be nothing but a planet) also moves round the sun along a similar path. These paths are not exactly circular, but slightly oval. They are elliptic in shape. Moreover, the sun is not exactly at the centre of these paths (or orbits as they are called) but a little to one side of it. So the distances of the planets from the sun are not always the same. The planes in which the planets move are different but very close to one another.

You have learnt already that the earth rotates on its axis. Nearly all other planets also do the same. You may particularly remember in this connection that as the earth goes round and round the sun, its axis of rotation which is inclined to the plane of its orbit at an angle of $66\frac{1}{2}°$, always points to a star called the 'Pole Star' or 'Polaris'.

A few particulars about the planets—

There are altogether 9 planets : Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto. Besides, there are a few tiny similar bodies called the minor planets (or *asteroids*).

The path of Mercury lies nearest to the sun ; that of Venus lies outside it and next in order come :—

Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto.

Since the sun is not at the centre of these paths and the paths are not exactly circular, the planets are not always at the same distance from the sun. Their average distances from the sun are as follows :—

Mercury—36,000,000 miles.
Venus—67,200,000 miles.
Earth—93,000,000 miles.
Mars—141,000,000 miles.
Jupiter—483,000,000 miles.
Saturn—886,000,000 miles.
Uranus—1,782,000,000 miles.
Neptune—2,792,000,000 miles.
Pluto—3,700,000,000 miles.

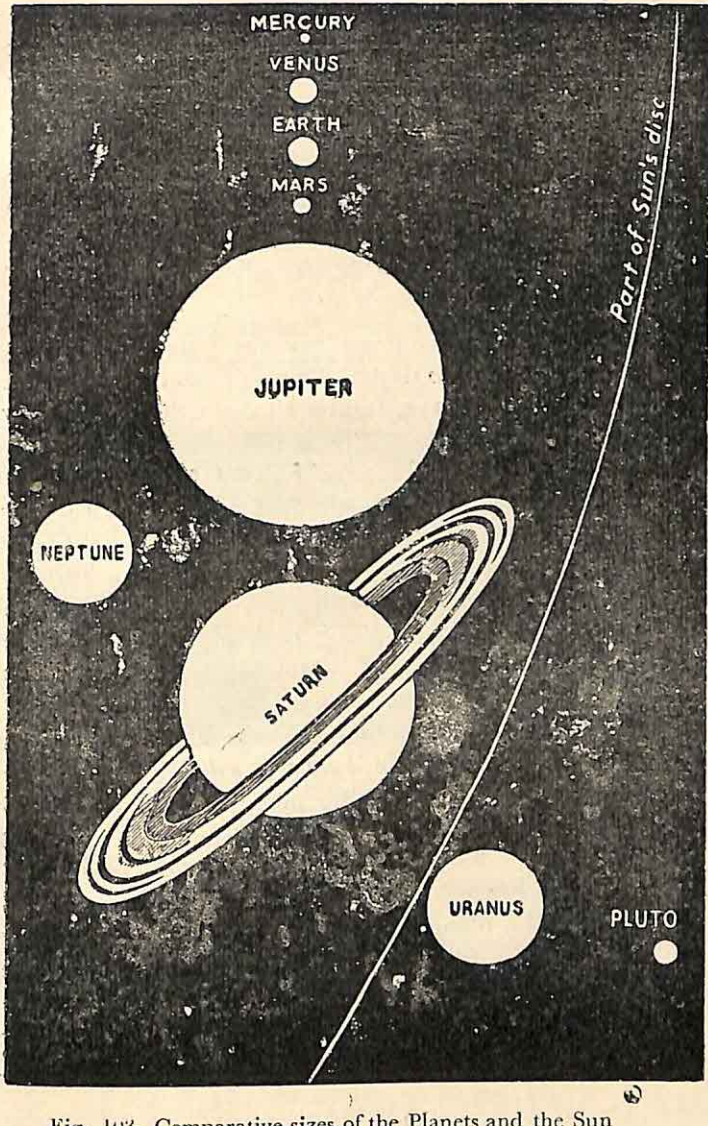

Fig. 103. Comparative sizes of the Planets and the Sun

In size Mercury is only 1/17th the size of the earth; Mars is 1/7th of the earth; Venus nearly equal to the size of the earth; while Jupiter 1,300, Saturn 734, Uranus 65, and Neptune 60 times the earth, Pluto is much smaller than the earth (Fig. 103).

The mean diameters of the planets are: Mercury 3,000 miles, Venus 7,600 miles, Earth 7,927 miles, Mars 4,200 miles, Jupiter 86,000 miles, Saturn 71,000 miles, Uranus 30,900 miles, and Neptune 33,000 miles; that of Pluto is not yet known.

All the planets move round the sun in definite periods: Mercury revolves in 88 days. Venus in 225 days, Earth in $365\frac{1}{4}$ days, Mars 687 days, Jupiter 12 years, Saturn 29 years, Uranus 85 years, Neptune 165 years and Pluto in about 248 years.

Each of the planets, in spinning round its own axis, takes a definite time to do so. The Earth takes 23 hrs. 56 mins. 4 secs., Mars about $24\frac{1}{2}$ hours, Jupiter a little less than 10 hours, Saturn a little more than 10 hours, Uranus about 10 hrs. 45 mins., and Neptune probably about 8 hours. Concerning the rotation of Mercury, Venus and Pluto, nothing definite is known.

The earth is a planet, and you know that the moon moves round it. The moon is called a *satellite* of the earth. Likewise, Mars has two, Jupiter nine, Saturn nine (doubtfully one more), Uranus four and Neptune one. Mercury and Venus have no satellites, and it is not yet known whether Pluto has any.

Although the planets look so bright none of them has light of its own. Like the moon they merely reflect the sun's rays and thus look bright.

You cannot see with the naked eye Uranus, Neptune or Pluto, or any one of the satellites of the different planets.

Of the remaining planets Mercury is very near the sun and so keeps always within the glow of the sun ; however, it can rarely be seen just before sunrise or just after sunset. Venus is a little more distant from the sun. So it is seen more clearly before sunrise or after sunset. It is on this account known as the morning and the evening star. It is the brightest-looking planet; Jupiter is next in brightness. Mars is a reddish planet.

Viewed through a telescope, Mars shows a few dark straight lines. Some astronomers believe that Mars is inhabited by living beings more intelligent than man, and the dark lines are canals dug by them.

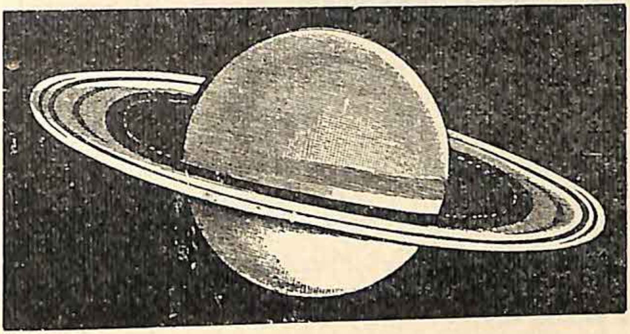

Fig. 104. Saturn with rings

Jupiter also is interesting to look at. You find on its body long-drawn streaks resembling clouds, the exact nature of which is yet unknown. But the most interesting Planet is Saturn. Seen through a telescope it appears to be a slightly oval body with three beautiful flat rings around it (Fig. 104). The rings do not touch the body of the planet, and are believed to be formed of millions of minute particles revolving at a tremendous speed around it.

The minor planets or asteroids—

The minor planets are very small compared to the other planets, the largest of them, called Ceres being only about 480 miles in diameter. There are altogether 600 of such minor planets. They move around the sun in the same way as the big planets, their paths lying between those of Mars and Juptier.

The other planets—

You can see from the differences in the distances of the planets from the sun, that the path of Venus lies nearest to that of the Earth and also within it. It happens, therefore, that as both the Earth and Venus are going round the sun, Venus comes sometimes between the earth and the sun, sometimes on the side of the sun opposite the earth and sometimes it makes different angles with the earth-sun line. These positions are exactly similar to those of the moon with respect to the earth and the sun. Venus has, therefore, phases just like those of the moon. Mercury also has similar phases.

Jupiter and the other planets, whose paths lie outside that of the earth, behave in a different way ; they do not show phases similar to those of Venus and Mercury, but they look nearly always full and sometimes only a bit worn away on one side.

How to tell the planets—

The movements of the planets are rather difficult to follow. It is true that their movements are confined to the belt of the zodiac in the sky, but in order to find out their exact locations you have to make many calculations. The table below tells you about their whereabouts in the coming five years and they can be seen with the unaided eye.

Year	Venus will be seen further from the sun		Mars	Jupiter	Saturn
	as morning star	as evening star	Will cross the north-south circle through the zenith at mid-night		
1940	September	April	—	November	November
1941	—	November	September	December	November
1942	April	—	—	—	November
1943	November	June	December	January	December
1944	—	—	—	February	December

COMETS AND METEORS

A comet—

In 1910 a very curious object was seen in the sky. A glowing starlike ball came towards the earth and as it approached, a long luminous tail was seen trailing behind and the tail was rather on the side of it opposite the sun (Fig. 105). After going round the sun it began to move away its tail sunk into its ball-like body ; and it gradually disappeared. Astronomers tell us that this body is moving along a long oval path around the sun and it will come back again to us in about 1985-86.

This is called a comet, and was discovered by Halley after whom it has been named. Comets generally move in regions far distant from the solar system. Sometimes they come within the influence of the sun and are drawn towards it. As they approach the sun a tail is formed, and again as they move away from the sun the tail gradually diminishes and finally vanishes. Some of the comets, like the Halley's Comet, are held captive by the planets and move regularly within the solar system. Comets are very light

in weight—not more than a pound ; they are composed of gases and dusty material.

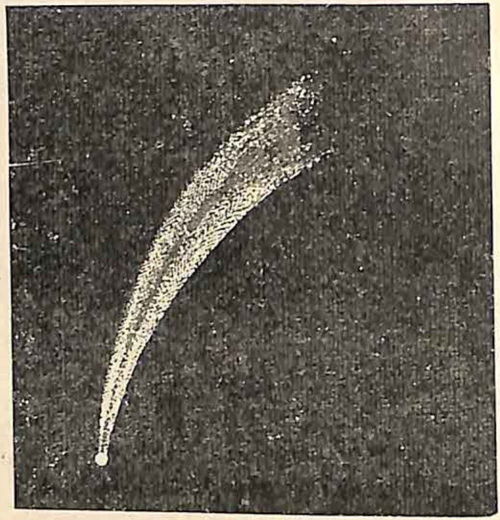

Fig. 105. A comet with a tail

"Shooting" stars or meteors—

Looking at a clear night-sky you may sometimes find a streak of light darting across the sky. This quickly fades away. The luminous object is a 'meteor', and it is popularly called a 'shooting star'.

Occasionally these lights actually strike the earth and then they are called meteorites. These meteorites are solid bodies made chiefly of metals like iron and nickel, or stony material ; they range in size from small potato to masses weighing thousand maunds.

Astronomers tell us that these bodies ramble in space and are attracted by the earth. In coming through the earth's atmosphere they are heated up by friction with the

air. This heating is so great that they become luminous and are sometimes converted into vapour. Some of these bodies reach the earth before they are vaporized.

Besides these occasional meteors, you may find showers of meteors every year regularly in the middle of April, and also towards the end of August and November. They are disrupted portions of comets coming within the sphere of influence of the planets.

Questions

1. What are the common planets you know? How do they move?
2. Explain the satellites.
3. What is Saturn?
4. Explain "shooting" stars.

CHAPTER III

THE STARS

What the stars really are—

The stars are really blazing masses of gases like the sun. Some of the stars are much bigger than the sun and much more brilliant. But they are situated at enormous distances from us and so look so tiny. The nearest star that we can see with the naked eye is called Alpha Centauri (the nearest telescopic star is Proxima Centauri). Its light reaches us in not less than 4·3 years. Astronomers classify stars visible to the unaided eye in six classes according to their brilliance, viz., first class (magnitude) stars, second class stars and so on.

Observing the starry vault—

The night sky above us appears to be a vault or dome bedecked with stars. If you observe this vault carefully you will find that the stars seem to be arranged into a few groups. Ancient observers, while looking at them, fancied that each group had the form of an animal or a human being and they named the groups, or constellations accordingly.

If you patiently observe this nightly picture for about two months, you will find that the picture does not remain the same all through. It changes gradually. Because the earth in its journey round the sun moves through space from one region to another, different parts of the heavens come to our view at different times.

How to tell the important stars and constellations—

The most important constellations in the sky are the Plough (or Great Bear or Dipper) and Cassiopeia.

Early in the nights* of April to July look to the northern part of the sky and you will find seven stars of second-class grouped together in the form of a plough. This is the Great Bear or the Plough. Two of its stars set apart from the other five are jointly called pointers, for they point to a star called the Pole Star or Polaris.

The Pole Star is so called because the northern end or northern pole of the earth's axis is always directed towards it. This star (it is a second-class star), therefore, does not share the daily westward movement shown by other stars or planets. The Pole Star never rises or sets. It always marks out north. Like the Pole Star the circumpolar stars which lie near the Pole Star do not rise or set. They go round the Pole Star in small circles.

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*All the following observations refer to early night observation.

Cassiopeia is just on the side of the Pole Star opposite the Great Bear. So when the latter is highest in the heavens, the former is lowest in it ; when the one rises in the east, the other sets in the west. Cassiopeia is best seen in early nights from November to January. On these nights you will find in the northern sky at some distance from the Pole Star, a few second-class stars arranged in the form of W. This group is Cassiopeia. The Pole Star lies to the head of this W.

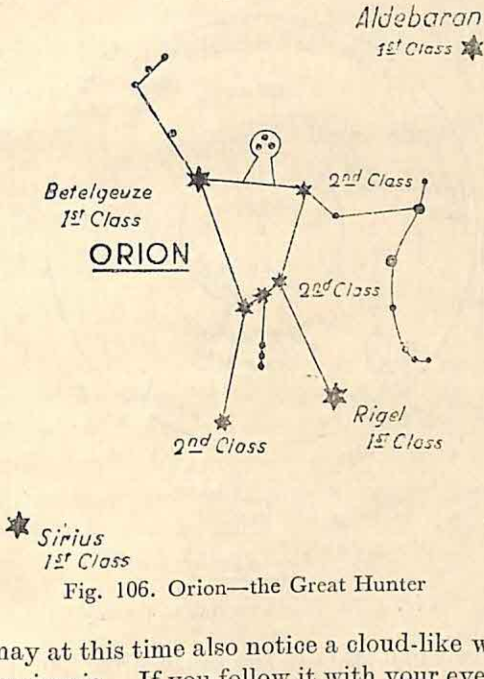

Fig. 106. Orion—the Great Hunter

You may at this time also notice a cloud-like white haze around Cassiopeia. If you follow it with your eyes you will find that it runs across the north sky as a band. This band, which is called the Milky Way, is a cluster of millions of stars. It is best seen from July to March.

Partly lying on the Milky Way and in the Central Part of the sky, is the grandest constellation in the sky known as Orion (Fig. 106). It is best seen from January to April. Old observers fancied it to have the form of a hunter, with a bow in one hand and a sword hung from its belt. Look

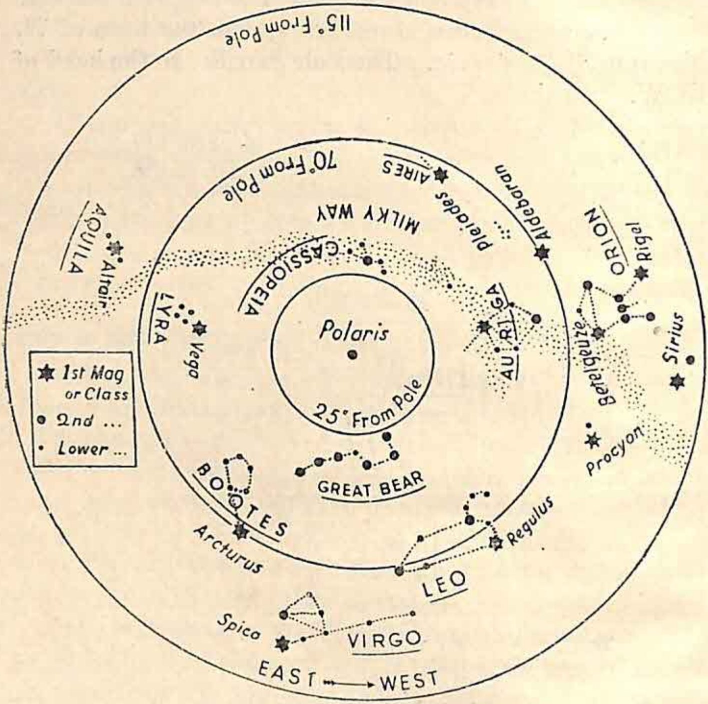

Fig. 107*a*. Northern half of the sky

at it. Three small stars to the north, from the head, two brilliant stars south of the head mark the shoulders, three second-class stars mark the belt, three small ones mark the sword across the belt, and a few small stars in a curved line to the east of the figure mark the bow of the hunter. The

red (first-class) star at the eastern shoulder is called Betelgeuze, while the one at the leg on the west is Rigel. A little to the west and north of Orion, when it is highest, is a pretty little constellation of six-small stars, called the *Pleiades*. This pretty group of stars really contains many more stars than those visible to us. It is best seen from December to March about the central belt of our sky.

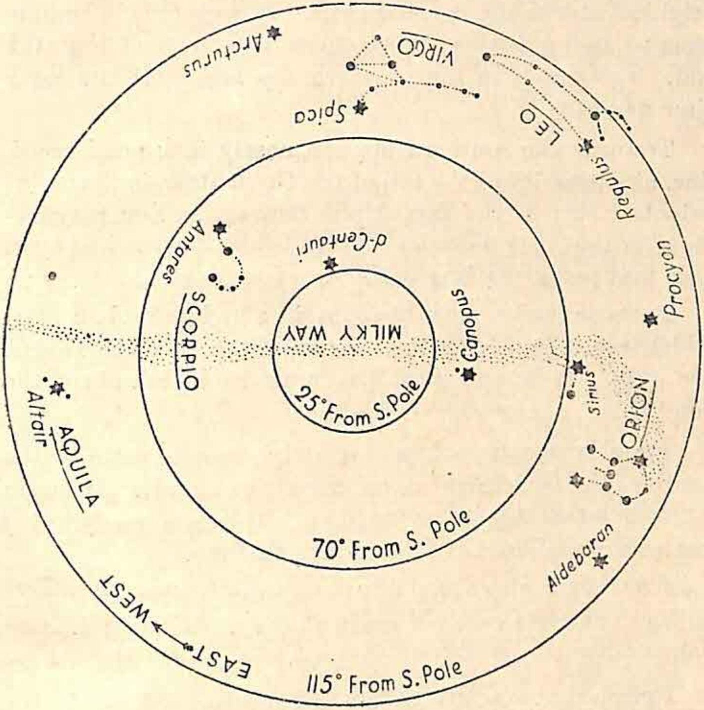

Fig. 107*b*. Southern half of the sky

To the north and east of Orion is another constellation called the Gemini or the Twins. It contains two first class stars, Castor and Pollux. They are best seen in the central

belt of our sky from January to April. They lie a little to the east of the Milky Way.

To the south and east of Orion, a little to the west of the Milky Way, is the brightest star in the sky, Sirius or Dog-star. It belongs to a constellation called the Canis Major. It is best seen from February to April towards the south. In a north-south line with Sirius is the second brightest star in the sky, Canopus. It is extremely remote from us, and probably 50,000 times more brilliant than the sun. It appears in the southern sky nearly at the same time as Sirius.

Towards the southern horizon nearly in a north-south line, at extremity of the tail of the Great Bear, is the third brightest star in the sky, Alpha Centauri. You may remember that it is the nearest star visible to our naked eyes. It is best seen from May to July.

Between Orion and Pleiades is a red first-class star, Aldebaran. It belongs to a constellation called the Taurus (or Bull). It is seen from December to March about the central belt of our sky.

Regulus is a first-class star and is seen a little to the south of the Great Bear when it is at its highest. It lies in a constellation called Leo (or Lion). It is seen nearly in the central zone of our sky from March to June.

Arcturus is also a first-class star, and is situated a little to the south and east of the Great Bear. When it is highest, it is seen from May to August.

Spica, almost south of the Great Bear, a little to the south of our mid-sky, is a first class star belonging to a constellation called Virgo (or the Virgin).

Antares is the reddest star in the sky. It belongs to a constellation called the Scorpio (or the Scorpion) of the

southern sky. It lies to the east and south of the Great Bear.

Vega (Lyra constellation) and Capella (or she-goat, Auriga constellation), are the two brightest stars of the northern sky. Capella has three tiny stars, or kids as they are called, by its side. It lies on the Milky Way, and is best seen from January to March. Vega is best seen from August to October.

The constellations Taurus, Gemini, Leo, Virgo and Scorpio, along with seven others not mentioned here, mark the belt of the zodiac i.e., the belt in which the moon, the planets and the sun are seen to move.

Questions

1. Give the picture of important constellations you have observed in a night-sky of a winter month.
2. What is the distinction between the fixed and moving stars ?
3. Why do some stars twinkle at night ?

CHAPTER IV

SOLAR YEAR AND SEASONS

Why the sun seems to move—

You have already seen that, as the earth spins on its axis, the sun along with the stars seems to move across the sky from east to west. But if you observe the sky day after day just after sunset you will also find that the same star does not occupy the same position in the sky every night. After a few weeks you will notice that the star which appeared near the western horizon just before sunset, is no longer visible in the sky, and the star which a few weeks ago at sunset was just rising in the east is now up in the eastern sky at the same hour. The stars seem to be overtaking the sun day by day or the sun appears to be lagging behind the stars in their march from east to west, or in other words, the sun is falling back from one star to another. If you carry on the observation, for a full year, you will find that the sun moves back in this way from one star to another and returns to the company of the same star just after a year, and that every year it seems to travel along the same path (this is called the ecliptic) among the same stars.

But the sun does not really move among the stars. If we could look at the sun in space the sun would be seen set against a background of stars, and as the earth revolved round the sun, it is this background of stars that continually changes and gives the picture of the sun moving among the stars. As the sun, the earth, and the planets are really in the same place, the sun's apparent path lies also in the zodiac.

How we reckon our days and years—

A day is commonly defined as the period of time taken by the earth to make one complete revolution round its

own axis. It is nearly 23 hours 56 minutes 4 seconds. Strictly speaking, however, a day (sidereal day) is the interval of time between two successive crossings of the zenith in our meridian by the sun. The highest point in the heavens is called the zenith. The period is called a 'Mean Solar day' and consists of 24 hours approximately. But all through the year this period of time is not always exactly the same. We take an average value of these slightly unequal periods of time, and so call it a 'Mean Solar day'. This is divided into 24 equal parts, each called an hour. Our clocks and watches keep this time.

The earth takes 365—mean solar days or rather 365 days 5 hours 48 minutes 45·5 seconds to make one complete journey (or revolution) round the sun. This period is called a "solar year". This solar year is the 'year' that we use in our practical life, but instead of 365¼ days, we count 365 days only. In this way a year is closed ¼ of a day earlier, that is, every 4th year one day earlier. To reconcile this, three consecutive years are closed with 365 days i.e., ¼ day earlier each, but the 4th year is prolonged by 1 day and so closes with 366 days. Such years of 366 days are called "leap years". For convenience in calculations, those particular years which are divisible by 4, e.g., 1936, 1940, etc., are taken as "leap years".

This procedure of making an adjustment between the number of days in the "solar year" and the "practical year", is not strictly accurate. For a solar year consists actually of 365 days 5 hours 48 minutes and 45·5 seconds, and not of 365¼ days.

Therefore, by prolonging every fourth year by 1 day over the usual 365 days, instead of by 4×(5 hours 48 minutes 45·5 seconds), it is lengthened by 4×(11 minutes 14·5 seconds) more. Every hundredth year will in this way be